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# THE ARMY/AIR FORCE RAMCAD PROGRAM

Progress Report through September 1989

G. Watts Hill
Frederick R. Riddell

January 1990

*Prepared for*
Office of the Under Secretary of Defense for Acquisition
(Research and Advanced Technology)

*Supported by*
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The document encompasses RAMCAD studies at IDA between FY82 and FY89. The goal of RAMCAD is to design reliability and maintainability into a product rather than accept these characteristics as by-products of a design driven largely by performance criteria. The report focuses on the three (TRW Federal Systems, Boeing Computer Services, and General Dynamics' Convair Division), recipients of Army/Air Force RAMCAD Program software development contracts with emphasis on the work done by General Dynamics Convair Division. Recommendations for further research are discussed under "Potential Avenues for Improvement."

This document was written at the request of the US Army Armament Research, Development, and Engineering Center (ARDEC) who are the co-sponsors of the General Dynamics RAMCAD Software Development Contract and have the responsibility for the technical direction of the contract.

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INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 89 C 0003
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# PREFACE

This report was prepared by the Institute for Defense Analyses (IDA) for the Office of Engineering Technology, Deputy Under Secretary (Research and Advanced Technology), and the US Army Armament Research, Development, and Engineering Center, under Contract Number MDA 903 89 C 0003, Task Order T-D6-553, "Applications of Systems Engineering Requirements to Development of a Unified Life Cycle Environment."

The issuance of this report satisfies subtask (4):b:iv, "Prepare a historical draft report with emphasis on the General Dynamics Convair Division 'RAMCAD' contract. The report will be in three parts:

1. IDA perspective from the contract start (September 14, 1987) until September 31, 1988.
2. IDA perspective from September 31, 1988 through August 1, 1989.
3. Recomendations for future directions and work in support of the ARDEC goals for a future RAMCAD System."

This paper was reviewed by Dr. Joel Tumarkin, a consultant to IDA.

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## Appendices

# I. INTRODUCTION

## A. INTRODUCTION

RAMCAD is the acronym for Reliability and Maintainability in Computer-Aided Design. The goal of RAMCAD programs is to design reliability and maintainability into a product rather than to accept these characteristics as by-products of a design driven largely by performance criteria. Field support costs are considered in all design efforts. Historically these costs have been a secondary consideration in the design of military systems and are not actively balanced against performance requirements. The goal of RAMCAD is to provide software programs that can be used in the design process to make an active trade-off possible. The aim is to reduce design errors which lead to the expensive "test and fix" methods in common use by the Department of Defense (DoD), or, if rework is not feasible, result in unnecessarily high support costs for the field equipment.

A working definition of RAMCAD is the use of computer-aided design technology to continually assess and improve the reliability and maintainability (R&M) characteristics of a product throughout its design cycle.

## B. EARLY HISTORY

In 1981, the Defense Science Board issued a report on the operational readiness of high performance systems [Ref. 1]. The board's major recommendations were to design reliability into the system from the initial design efforts and to mature that capability prior to full-rate production. This recommendation captured the attention of the Director of the Weapon Systems Support Improvement Group[1] at OSD, who was charged with ensuring that R&M issues were properly addressed during the full-scale engineering development of new weapon systems.

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1 Mr. Russell Shorey.

The Director approached the Institute for Defense Analyses (IDA) with a task to assess the impact of new technology on the R&M of future weapon systems. As a result, an 18-month study of this problem was undertaken. The study focused on case studies of current weapon systems and studies of the potential impact of new technologies. Six weapon systems and sixteen technology areas were selected, and a working group was formed for each. Each working group met monthly for six to eight months and produced a report on its subject area. The documentation was summarized in a four-volume report that included an Executive Summary, a Core Group Report, a Case Study Analysis, and a Technology Steering Group Report [Ref. 2].

Following the extensive study, which produced a multitude of recommendations, IDA undertook an analysis to identify key lines of attack on the R&M problem. This study was sponsored jointly by the Director of the Weapons System Support Improvement Group and the Director of the Engineering Systems Group in the Research and Advanced Technology Office.[2] The latter oversees all of the DoD technology base R&D programs that deal with platforms and their weapons.

Two approaches emerged from this effort. The first plan was to address the benefits and the problems involved in replacing the massive paperwork that defines the operating and support needs of a modern weapon system with digitized data derived directly from the prime contractor's computer-aided design/computer-aided manufacturing (CAD/CAM) systems. The plan was based on the concept that information age technology could reduce the workload associated with handling the extensive engineering and technical data needed to support a weapon system. Current technology could also be used to vastly reduce the problems of updating this information by providing a single-point-of-entry system for the continuous flow of design changes that occur due to engineering modifications.

The formidable task of evolving a plan to address this problem was undertaken by an ad hoc DoD-Industry Working Group on Computer-Aided Logistics Support (CALS), formed under the auspices of IDA. This group coined the acronym CALS to describe its efforts and, in an intensive series of meetings involving more than 80 people (including subgroups) over 7 months, produced a 5-year plan for evolving a completely digitized logistics system. They also made recommendations as to how the plan could be

2 Mr. Ray Siewert.

implemented [Ref. 3]. These recommendations were eventually approved by the Deputy Secretary of Defense. Appendix C contains an Executive Summary of the initial CALS Implementation Plan.

The second approach that emerged from the IDA analysis of the R&M study was to address how the design process might be modified to obtain a better balance between R&M needs and other performance requirements. Concurrent with the CALS working group effort, an IDA study of this problem was initiated by the Air Force Human Resources Laboratory through the Office of the Secretary of Defense (OSD) Weapon System Support Improvement Group. IDA assembled an ad hoc tri-Service group from the R&D community, chaired by the Air Force to guide the study, which became known as the RAMCAD study. About 8 months after this tri-Service group began work, it became a Joint Logistics Commanders (JLC) Subcommittee on RAMCAD, reporting to the JLC Logistics R&D Committee. The study at IDA continued, and eventually led to the letting of contracts with Joint Service support for the development of RAMCAD software, which is described in the following section.

At this point, an explanation of the relationship of CALS to RAMCAD is appropriate. The CALS working group addressed the formation of digital data and its distribution through the logistics system. In addressing the formation of the digital data in the prime contractor's CAD/CAM system, the CALS group recommended that reliability and maintainability analyses be incorporated into the design system. One major recommendation of the CALS group was that RAMCAD be implemented by contractors as soon as possible [Ref. 3].

Interest in CALS has grown quickly. Each of the Services now has a CALS office to coordinate internal activities, and each of these offices has some degree of interest in RAMCAD. The main thrust of the Service CALS efforts seems to have been directed at transferring digital data into their logistics systems and distributing it efficiently. More recently, however, interest in improving the design process to create a higher quality product has grown. The Air Force's Unified Life Cycle Engineering (ULCE) initiative, various DoD programs, and, most recently, OSD's Concurrent Engineering initiative are all focused on improving the design process. The CALS office at OSD recognized that their interest in design extended beyond RAMCAD to other supportability and producibility issues. To reflect this broader view, the acronym CALS was expanded from Computer-

Aided Logistics Support to Computer-aided Acquisition and Logistics Support. The CALS Service offices have recently expanded their interests to include concurrent engineering.

## C. EVOLUTION OF THE RAMCAD SOFTWARE DEVELOPMENT PROGRAM

From 1984 to 1986, the R&M efforts within DoD had two main thrusts. One was to evolve a research and development (R&D) program plan that could be used by the tri-Service group to accelerate the introduction of RAMCAD into use by defense contractors. The other was to track the evolution of R&M analysis tools by vendors and to understand contractors' attitudes about using these tools to develop weapon systems.

The initial effort to develop an R&D program focused very quickly on the need for a computer-based solution as it would offer the flexibility they perceived was needed. Most defense contractors used computers (commonly called workstations) in their design offices. The development of a computer software tool that would integrate R&M analysis tools and be available during the design process was the goal. The combination of the proposed software and computer became known as the RAMCAD workstation. The question of how to pursue such a development went through numerous iterations. A two-phase approach was generally agreed upon. Phase I was to involve creating a RAMCAD workstation using existing commercial R&M analysis tools. This workstation would demonstrate the ability to rapidly access R&M analyses and apply them to design data acquired directly from a CAD/CAM or computer-aided engineering (CAE) system. The goal of Phase II was to upgrade this prototype using new software and new technology as appropriate. This two-phase approach eventually translated into Tasks I and II of the Program Research and Development Announcement (PRDA)[3] that was eventually issued by the Air Force.

Another issue addressed in developing the program plan was whether to assign the lead role in the R&D program to a university or a contractor. A university-centered consortium, which would involve a number of contractors, with the university serving as integrator as well as providing innovative ideas for Phase II, was somewhat appealing. A number of possibilities for such consortia were investigated with universities across the

[3] The full context of this announcement is contained in Appendix A.

country. None of these came to fruition, mainly because the universities were unwilling to accept the strict contractual requirements that the Services felt necessary.

IDA, who was tasked to assist the tri-Service group in the development of a RAMCAD development plan, continued to pursue its development. As an adjunct to developing the R&D plan, some specific aspects of a RAMCAD workstation were investigated in small, narrowly focused subtasks given by IDA to the University of Maryland, Boeing, and TRW.

### University of Maryland

The University of Maryland effort, the largest of these subtasks, addressed the practical (rather than theoretical) problems of integrating thermal and wiring analyses of printed circuit board designs to arrive at optimal component placements from a reliability viewpoint without violating wiring rules [Ref. 4]. An unforeseen result of this work was the conclusion that, in some cases, modifications to commercially available analysis packages would have to be made to integrate them into an optimization scheme.

The work at Maryland has since continued with other sponsorship and led to the development of the University of Maryland Center for Computer-Aided Life Cycle Engineering (CALCE). The CALCE Center is an industry/university cooperative research and development center sponsored by the National Science Foundation. The center's primary focus is developing new techniques for designing electronics products for reliability, maintainability, and supportability. CALCE is the only center of its kind in the country that is focusing on design for supportability of electronics. A number of major defense electronics suppliers are members of the center, including Westinghouse, Texas Instruments, Digital Equipment Corporation, Northrop, General Electric, Allied Signal, and General Dynamics.

### Boeing

Another aspect of the RAMCAD workstation was investigated by Boeing. The Boeing subtask involved exploring the possible use in RAMCAD of an executive controller computer program they had developed to access and activate analyses programs resident at different locations on a network [Ref. 5]. Boeing was able to demonstrate the ability to send and receive information from other systems on the same network that had performed tasks requested by the executive controller. This exchange and processing of information took place while other work was being done on the user's system. This allowed the maximum use to be made of other computer systems on the network while leaving the user only one primary system to be concerned with.

### TRW

TRW was tasked with creating a rapid prototype of a RAMCAD workstation to scope the man-machine interface problems--to determine what R&M information would be needed, and in what format, to assist the designer of a printed circuit board [Ref. 6]. A prototype interface was created with the input from a very limited group of designers. A video tape of the prototype was produced and delivered to the Air Force.

The insights from all three of these subtasks were used in detailing the work to be done in developing a RAMCAD workstation prototype [Ref. 7].

The other major thrust of the IDA RAMCAD study was to monitor pertinent developments at software vendors and at contractors and promote interchange of ideas. Direct contact with vendors and contractors through visits and telephone conversations and technical interchange meetings (TIMs) were held [Ref. 8]. Close contact was maintained with a National Security Industrial Association (NSIA) committee investigating RAMCAD issues [Ref. 9] in the avionics industry, and a RAMCAD bulletin was published.

Through these efforts, it became clear that the design environment was rapidly changing. Initially, many vendors and contractors talked of support for RAMCAD goals but made no effort to support RAMCAD. By the end of 1986, however, their R&M activities had increased substantially. In fact, IDA developed a catalog of R&M software but was unsuccessful at keeping it current because of the rapidly changing nature and amount of software to be catalogued.

From this monitoring effort, an extensive file of information was collected and a key-word-in-context index was developed to make it easily accessible. This information was essential in forming recommendations for the tri-Service group concerning the detailed nature of the R&D program plan [Ref. 10].

# II. THE RAMCAD SOFTWARE DEVELOPMENT PROGRAM

## A. STRUCTURE

To implement the R&D program plan, it was finally decided that the Air Force would take the lead and issue a PRDA[4] indicating an interest in

- The development of a prototype RAMCAD system (Task 1)
- The accomplishment of fundamental research in this area (Task 2)
- The development of an engineering curriculum incorporating RAMCAD (Task 3).

The PRDA further described each task in terms of subtasks.

The announcement generated an unexpectedly large response. Fourteen proposals were received and a tri-Service source selection board was assembled in July 1986. As a result of their deliberations, three contractors were selected as most responsive to the intent of the PRDA, mainly TRW, Boeing, and General Dynamics. A protracted series of activities to allocate the funds and negotiate contracts then followed. TRW was under contract in early 1987, but the contracts with Boeing and General Dynamics were not signed for another six months. The Navy was unable to provide funds so the funding responsibility fell to the Army and the Air Force. The Army agreed to shoulder the initial cost (first two years) of the General Dynamics contract, and the Air Force funded the TRW and Boeing contracts. The TRW contract was the only one that covered all three tasks; however, it was eventually terminated because the Air Force could not meet the financial burden. The Air Force also wanted to ensure that they would be able to meet their financial commitment to the Army to fund the final two years of the General Dynamics contract. The following sections describe the outcome of these contracts. The GD program has been closely monitored by IDA and detailed descriptions of that work follow in Chapter III.

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[4] Program Research and Development Announcement. See Appendix A.

## B. THE TRW CONTRACT

### 1. Task I

TRW was to develop a RAMCAD prototype, focusing primarily on electronic design. The electronic assembly chosen was a typical frequency synthesizer for an avionics system. The actual design was not new; it had been used in teaching engineering students. In recent years, the majority of this design has been replaced by a single integrated circuit. TRW intended to develop a prototype RAMCAD system using a proprietary development system, which they had created, that allows the rapid prototyping of the system display to investigate interactive design and the human interface. They planned to integrate off-the-shelf commercial software packages that would be operated by an executive control program whose display would be developed by their proprietary system.

### 2. Task II

This task was aimed at using the prototype developed under Task I and the lessons learned from it, to develop a fully functioning system that would be useful to the engineering community. Because this task involved new approaches to the engineering process, the university team members from Task III were included in this effort.

### 3. Task III

Task III focused on finding ways to influence the engineering academic community to address and teach a more complete design process. TRW selected the Virginia Polytechnic Institute (VPI) as the subcontractor to perform this task.

### 4. Conclusions

Due to a lack of sufficient DoD funds, the TRW contract was terminated prematurely in November 1987. Thus the conclusions derived from these efforts were limited.

The TRW tasks, while limited in scope, did contribute to the primary goals of RAMCAD. TRW's survey and analysis of the reliability, maintainability, and supportability (RM&S) software tools available to the engineer and the discussion following their survey has influenced workstation design. Industry has moved forward in addressing the lack of software and the need for integration with CAD and CAE systems in particular. An example of the influence on industry was shown where TRW efforts strongly influenced the future development of Valid Logic System's CAE software tools. Valid Logic Systems is a major supplier of CAE software to the DoD industry base.

The work performed by VPI also contributed to the RAMCAD goals. The need to address RM&S in the curriculum has been addressed. Course changes have been implemented at VPI. That school, along with other universities, is now participating in other sponsored efforts to implement the goals identified by this work.

## C. THE BOEING CONTRACT

Boeing originally proposed performing Tasks I and II but, due to budget constraints within the Air Force, they were awarded a modified version of Task II only. One of the main factors for the selection of Boeing was their plan to look at how artificial intelligence (AI) technology could be used in addressing the engineers' needs in a future RAMCAD system.

The contract originally awarded to Boeing emphasized the development of software for the Air Force but was later modified to allow a refocusing of the effort toward research programs. The Boeing work began many months after the other contractors' efforts, and the government had already begun to receive instructive feedback from the other two contractors. One of the first lessons was how little was actually known about the design process and its associated testing. It was realized that, without some preliminary work of the type outlined in Task I, progressing with the standalone Task II effort would be difficult. Boeing and the government decided to focus initially on obtaining a clearer view of the design process, to enable a better understanding of what RAMCAD could contribute. Boeing also wanted to attempt to capture the senior engineers' experience through the use of AI-based/knowledge-based interviewing techniques.

As a result of this effort, Boeing has documented the engineering process for an electronic designer, at Boeing, in one of the best descriptions available to date. They are also experimenting with AI and its role in reliability through built-in testability (BIT) capability. The avionics system selected for the initial research was the Ejector/ Stores Interface Unit (ESIU) of the B1-B SRAM II Stores Management System (SMS). The ESIU is representative of the type of avionics designs currently found in the aerospace industry. It contains a mixture of off-the-shelf and custom-built components including microprocessors and has a comprehensive BIT capability. At the time of selection, the ESIU was an active design project, which provided access to designers during the actual design process rather than during a re-creation of a design effort..

In conjunction with its internal RAMCAD work, Boeing is also working with Carnegie Mellon University on studying the design process with the goal of attaining total automation of the design. Functional specifications for small computers are given to Carnegie Mellon's computer-based design system, which then creates a complete design for a small computer module that meets the performance specifications. The outnut of their system is a schematic with recommended part values, as well as analysis of its operational characteristics.

The Boeing research will continue for approximately 12 months. The final result of this effort is difficult to determine, since reports are not due until contract completion in FY91.

## D. THE GENERAL DYNAMICS CONTRACT

The General Dynamics (GD) contract covered Task I only; however, GD was to develop a prototype RAMCAD system for three areas, digital or analog electronics, mechanical design, and structural design, rather than for only one area as the PRDA required. The rationale for this change was that looking at three disciplines, their similarities, differences, and interactions, would improve understanding of what actually occurs in the design process and thus what RAMCAD prototypes require.

The GD work was separated into two phases. The first was developing a working prototype of a RAMCAD system with a limited number of commercially available software programs interacting with other software on the system. This prototype will serve as the basis for the foundation of the RAMCAD system software to be developed for delivery to the program's sponsors (Air Force and Army). Completion of the prototype will meet the conceptual intent of the original PRDA. The second phase will consist of further refinement of the prototype system and will incorporate some of the work as outlined in the original PRDA Task II.

The progress to date under this contract is reported in detail in the next chapter. Copies of IDA's monthly comments on GD's efforts are contained in Appendix B.

# III. THE GENERAL DYNAMICS PROGRAM

This chapter summarizes the information in the monthly progress reports submitted by General Dynamics (GD). Detailed IDA comments on these reports are contained in Appendix B. The course of the GD development effort was approved at the proposal and award stage of the contract. This course has been pursued without any major changes partly because the contractual restrictions were not conducive to change.

Following a kick-off meeting in July 1987, GD began its efforts by investigating three areas:

- The design process (as defined by GD's own engineers) and what was involved--the steps and drivers associated with a design. This investigation was accomplished through interviews with engineers from GD's Convair division.
- A market survey of all currently known software programs for use with a proposed RAMCAD system. The programs had to be commercially available and could be used in a workstation environment. (Software for mainframes was not ignored, but GD's plan was to develop a RAMCAD system on a workstation and/or microcomputer.) The survey produced some interesting results. In electronic design, a wide selection of software programs were available, but the options for mechanical reliability design were very limited. The electronics industry was more advanced in the development of software-based reliability analysis tools than were their mechanical counterparts.
- A RAMCAD system concept that took into account the results from the investigation of the design process and the software survey. The government wanted to see the results of a RAMCAD system implemented by industry as soon as possible. GD determined that the most expedient approach would be to use software already developed, integrate the different packages in a manner that would allow them to exchange information directly or indirectly, and that was consistent with the process already in place.

During the first year, GD gathered details to learn more about the design process. The interviews with engineers continued until they felt they had gathered sufficient information. The next step was to determine how to present all of the information gathered. From this research it became evident that the three engineering disciplines--mechanical, structural, and electrical--used significantly different approaches. Each had its own methodology when performing design, reliability analysis, and support analysis. These differences led to a problem, which has to be addressed, determining how to make design trade-offs among the different disciplines.

The GD system concept went through minor changes during this year. The primary driving factors for these changes were related to the vendors of the computer equipment used and the available software. The primary differences among the vendors were related to the following areas:

- The viability of the software and hardware (i.e., was the product available and did it operate as advertised)
- The cooperation of the equipment and software vendors in supplying information on how the products functioned.

## GD Concept and Prototype

The overall GD concept is described as follows. First, the user sees and uses only one system. All of the various programs used in the RAMCAD environment are linked and presented to the user through a common interface--even if the programs reside and are executed on other computer systems connected to the system network. The RAMCAD Navigator communicates with the program that is needed for analysis. The Navigator starts the program, supplies the information required to do the analysis, stores the answer, and presents the results to the engineer in a manner consistent with his request. This should allow a modular approach to facilitate the addition of new features to the RAMCAD system as software and systems progress.

The preliminary RAMCAD advanced prototype system focused on electronics design and has been built and demonstrated. The current prototype work now under development will incorporate mechanical and structural as well as electrical design.

Figure III-1 is a representation of the architecture of this system. The RAMCAD system software was developed in both languages of C and Oracle (an SQL-based data base) to help ensure that minimal effort would be necessary to move the system to a new platform; the government considers transportability an important issue.

## FUNCTIONS OF THE RAMCAD NAVIGATOR

When the user requests analysis via the user interface:

1. The user interface calls for the analysis application program execution commands from the Navigator and...
2. Establishes network communications with the application program host. The application program may be located on the same computer as the user interface or on a remotely located computer.
3. The Navigator tells the DBMS to send the required data to the Application Program Input Format Table.
4. The data is formatted for input to the application program.
5. The formatted input file and application program start-up instructions are passed to the application program for computation.
6. The application program performs the analysis function and sends the output into the Application Programs Output section of the Navigator.
7. When the data transfer is complete, the Navigator sends the data to the Output Translator. The Translator sends data to. . .
8. The Main Database via the Navigator's Database Input Formats Section and. . .
9. The User Interface for the engineer's analysis.

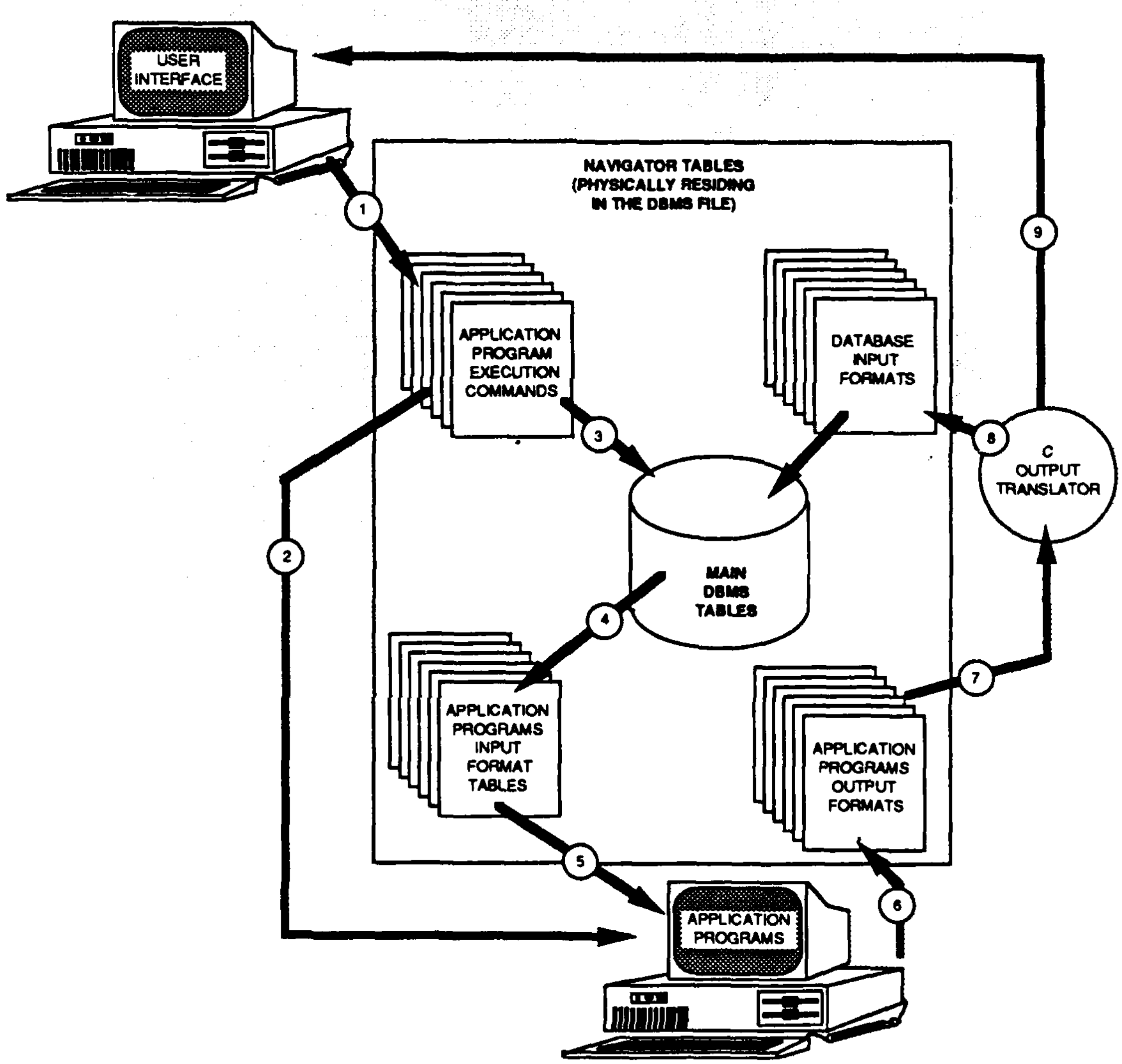


**Figure III-1. GD System Concept**

# IV. CONCLUSIONS

## A. THE CHANGING RAMCAD ENVIRONMENT

In the five years that have elapsed since the formation of the first tri-Service RAMCAD group, the entire CAE environment has changed radically. Vendor and contractor activities relevant to RAMCAD issues have increased substantially. If the PRDA tasks were to be rewritten today, far more ambitious goals than were initially set would be pursued. This is due to the rapidly advancing computer environment of computer systems and new computer program development tools, particularly for the prototype development of Task I. This rate of change was partially recognized and led to the incorporation of some of the research elements of Task II into the General Dynamics contract. Nevertheless, the impact of the prototype on the outside world will be less when it is finally completed than would have been the case if it had been completed earlier. Had the start of the program been on the time schedule originally planned and the funding level been as planned, RAMCAD would be finished a year earlier. More contractors would have been influenced by RAMCAD innovations and be further along today in its use.

During this time a major change in the DoD environment in relation to weapon systems design has also occurred. As noted previously, the CALS initiative has gained great momentum and in the process has expanded to full-fledged support of the goals of the concurrent engineering initiative. The goals of RAMCAD and concurrent engineering, in terms of producing a better product, are identical. Both call for the same type of changes in the design process to accomplish this goal. RAMCAD is thus considered a major element of concurrent engineering by the CALS community.

Today, a closely related recent OSD initiative is Total Quality Management (TQM), which has the goal of continuously improving the quality of the work output of every element of an organization, both staff and line.[5] Concurrent engineering in most industrial concerns is treated as the engineering element of the company's TQM program. Much of the growing industry interest in RAMCAD can be attributed to the fact that it is considered a major element contributing to the larger concurrent engineering and total quality management programs.

## B. FUTURE PROSPECTS FOR THE GENERAL DYNAMICS PROGRAM

IDA noted at the Preliminary Design Review (PDR) (Appendix B, p. B-19) that GD is developing a workstation and network that allow a more rapid R&M evaluation of a design. To what extent these elements will be turned into a design tool--become an integral part of the design trade-off process--remains to be seen. GD's Integrated Manufacturing System (IMS) project includes RAMCAD as part of the company-funded development program at Convair, which indicates that the workstation and network are becoming part of the trade-off process. RAMCAD as it exists today has already influenced how GD does business. It was used on the advanced cruise missile program to validate work done by a subcontractor to ensure compliance with the design specifications for their task. RAMCAD was also used in the conceptual design phase of a new missile for the year 2000. GD has invoked an internal policy requiring that a baseline system (existing design) be compared against any new concept for improvement. GD has reported that the current advanced prototype RAMCAD was used successfully to test the effects of new technologies on an existing design.

One of the useful results of the GD program is a practical evaluation of the similarities and differences between RAMCAD analyses for mechanical, structural, and electronic systems. An issue remaining to be addressed is the integrated use of these tools on one design. While the tools could be used individually to evaluate a design once it is complete, the problem of when and how to use them interactively during the design to effect more optimal R&M results requires further investigation.

Another potentially useful result of the GD program is in addressing the problem of analyzing mechanical reliability statistically as is routinely done for electronic systems.

[5] *The impact and importance of TQM are reflected in a memo from then Under Secretary of Defense for Acquisition, Robert Costello, which calls for implementation of TQM. The memo is contained in Appendix D..*

Though experimental approaches exist, there is a fundamental question as to how useful this type of analysis may be. Addressing this question would be a very useful result.

## C. POTENTIAL AVENUES OF IMPROVEMENT

### 1. *How does one do a trade-off among different design disciplines?*

The GD RAMCAD system addresses three major engineering disciplines--electrical, structural, and mechanical. Each was being addressed individually. The system designer will have to determine the optimum trade-offs to be made among these three disciplines which each discipline is competing for the same design space. A method for assisting the designers in performing such trade-offs is needed. A major issue is determining whether these trade-offs are necessarily subjective or whether they can be made quantitative.

### 2. *Research the need for and development of a consistent user interface among the different software packages integrated in a RAMCAD system.*

The commercial computer market has demonstrated the benefits to be gained in time and training cost of a common method for operating different computer programs. It is this common mode of operating a computer system that has led to the rapid development and growth of the "user interface." Both Microsoft Corporation and Apple Computer are attempting to develop a standard graphics-based representation of the computer operation. They are the two largest suppliers of computer operating systems in the world.

The current RAMCAD advanced prototype is just beginning to address how to best present the user with the requested information and the possibility of having all similar functions from the different analyses programs operated in the same manner. An example of this would be in printing a report when the analysis is completed by a program. If the interface to the user is the same for all programs when the user wishes to print, then they know how to do it for all the other programs.

If we apply this knowledge gained in the development of the user interface to RAMCAD, we can increase the acceptance and use by the design community.

### 3. *Is RAMCAD a tool for a single designer or for assisting a design team that represents the different disciplines associated with the product definition?*

The current RAMCAD system, as demonstrated by GD, is designed to interact with one user. With the advent of TQM, which emphasizes a team approach, the system may need to be expanded in a manner that will facilitate a team of designers working interactively through a network while developing a new design. The system should also be modified to address the team's need to work face to face, such as during a design review meeting.

4. *Data Availability in Computer-Readable Formats.*

Technical data should be available for electronic components in a computer-readable format. Most of the technical data available today on electronic components is in printed form, which requires that this data be read by an operator, entered into the system, and formatted for the CAD or CAE data base system of choice. To add to this problem, the format of the information stored on different systems varies with the developer of the CAD or CAE program being used. Standardization among the different CAD or CAE data bases would allow electronic transfer of information. The component manufacturers could produce the necessary data in an electronic form for less than it cost them to print it and allow for updates or additions to their information to be available in a matter of days, not months.

5. *Computer tools (Software) Address the Mechanical and Supportability Disciplines*

The RAMCAD program software survey revealed that the existing software is geared to the electronics industry. Software for non-electronic environments has probably not been developed because the methodologies for these areas do not lend themselves to an automation process. Thus, current CAE and CAD software was developed to address specific needs of the workstations for electronic designers. Further investigation is necessary to determine what tools are needed for the non-electronic environment and how this environment can be represented in an electronic model.

6. *Quality Control in Software Tools*

In GD research of software tools they discovered that some software reported to represent the Military Standard 217 Handbook produced errors. The results generated by the program were shown to be incorrect based on a manual check of the same calculations.

Software tools, while being developed, must be checked and rechecked for consistency and the accuracy of their output; otherwise the design community will not use them.

### 7. *Management Acceptance of and Support for RAMCAD*

Until management acknowledges that RAMCAD can be used to deliver both a near-term and long-term cost benefit, it may be discussed but will not be used in the design process. If management does not recognize the need to emphasize the use of RAMCAD, its use may be limited to creating electronic data for CALS.

## D. TRANSITION PLAN FOR PICATINNY ARSENAL

Having reviewed the history, development, and current status, we must now address the question, "What should be the next step for the RAMCAD program?" We need to move RAMCAD from the lab into an actual DoD environment to properly determine its usefulness and next direction for development. Since the US Army Armament Research, Development, and Engineering Center (ARDEC) at Picatinny Arsenal is the main sponsor of the General Dynamics RAMCAD program and since ARDEC works on weapons design from concept through first production, this would be an excellent environment for RAMCAD. It is essential that a proper implementation plan be researched and developed. Issues such as computer system and other compatibilities within the existing engineering process at Picatinny must be considered. Engineering is particularly important because of the many changes that are required to introduce RAMCAD and eventually TQM techniques.

Another issue for implementation will focus on the reliability analyses that would be acceptable to the Picatinny design community, particularly in mechanical design. The software selections made by GD are rational for a demonstration but, as noted in the PDR comments (Appendix B), what the mechanical engineering design community will accept or need is still to be determined.

An approach to development of a plan on how to best introduce RAMCAD at Picatinny Arsenal is contained in Appendix E. This document discusses the process for developing such a plan.

# REFERENCES


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# Appendix A

# THE PROGRAM RESEARCH AND DEVELOPMENT ANNOUNCEMENT[1]

## A. RAMCAD SOFTWARE DEVELOPMENT (ADVANCED DEVELOPMENT), PRDA #86-16-MRS

This is a Program Research and Development Announcement (PRDA). The Air Force Human Resources Laboratory (AFHRL/LR) is interested in receiving proposals (technical and cost) on the research effort described below. It is desired that proposals in response to this PRDA be submitted by 1530 hours, 17 June 1986,[2] addressed to: HQ Aeronautical Systems Division, Building 7, Area B, Attention: ASD/PMRSC, Wright-Patterson AFB, OH 45433-6503. Proposals submitted must be in accordance with this announcement. There will be no formal request for proposal or other solicitation request in regards to this requirement. Proposals submitted should be in general accordance with the AFSC Guide for Program Research and Development Announcement (AFSCP 70-4, dated 25 April 1984). A copy of this guide is available upon request from ASD/PMR-1, WPAFB, OH 45433-6503, (513) 255-3825. Offerors should be alert for any PRDA amendments that may be published. The selection of one or more sources for contract award will be based on a scientific and engineering evaluation of the proposals received (technical and cost) to determine the relative merit of the approach taken in response to this announcement. New and creative solutions are of primary interest and will be ranked first in the evaluation process. Cost is ranked second. No other evaluation criteria will be used in the source selection. Proposals must provide new or unique concepts, ideas, or approaches to be considered for award. Responses should reference the above PRDA number. The Air Force reserves the right to select for award, all, part, or none of the proposals received. The cost of proposal preparation in response to this announcement is not to be considered an allowable direct charge to any resulting contract or to any other

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1 Synopsis in Commerce Business Daily (R&D Sources Sought); published 15 May 1986.

2 *Extended to 27 June 1986.*

contract. It is, however, an allowable expense to the normal bid and proposal indirect cost as specified in FAR 31.205-18. Proposals must be submitted in an original plus three copies. The Air Force Human Resources Laboratory has initiated several efforts to integrate Reliability and Maintainability into Computer-Aided Design (RAMCAD). It is the intention of the Laboratory to establish a cooperative effort consisting of universities and industry members to conduct research and development in the area of RAMCAD. This effort is directed at supporting the establishment of the RAMCAD cooperative effort. As a result the purposes of this effort are:

(1) The development of a prototype RAMCAD System

(2) The accomplishment of fundamental research in this area

(3) The development of an engineering curriculum incorporating RAMCAD.

It is anticipated that offerors would respond to one or more but not all of the tasks. The technical proposal must include an outline and full discussion of the nature and scope of the research, the method or technical approach, and the expected results.

## B. (1) REQUIREMENTS

### Task 1. Prototype RAMCAD System

The objective of Task 1 is to develop application software and/or a translating device capable of integrating stand-alone commercially available reliability, maintainability, and supportability (RM&S) software with Computer-Aided Design software. Task 1 at a minimum consists of the following subtasks:

(a) Simulate the design process for an aerospace-related defense equipment within one of the following areas.

 (i) Digital or analog electronics

 (ii) Mechanical design

 (iii) Structural design.

 The complexity of this equipment design, whether electronic, mechanical, or structural, shall be roughly equivalent to that of an electronic device with a minimum of 25 components representing at least 4 component types.

(b) Identify and document the information requirements to accomplish reliability, maintainability, and supportability analyses consistent with the appropriate Military Specifications and Standards for the design selected in Subtask 1a. This shall include the identification of major competing design attributes for performance, reliability, maintainability, supportability, cost, and schedule for the design selected in Subtask 1a.

(c) Identify, classify, and document all commercially available software to accomplish reliability, maintainability, and supportability analyses to meet the requirements identified in Subtask 1b. This classification shall include the computer(s) on which the software runs, the phase of design in which it is used, and the function of the analysis within the design. The classification shall also include the softwares' input and output requirements, data formats, modeling capacity (i.e., the size of the problem on which it is typically used), and any other known limitations or requirements.

(d) Develop and document a conceptual schema for integrating a minimum of three diversely different RM&S softwares together with a CAE system.

(e) From experience and interviews with a representative cross section of design engineers, develop and document the man-machine interface requirements (i.e., user friendliness) necessary to ensure acceptance by the design engineers of the integrated system to be developed in Subtask 1f.

(f) Prepare a plan for developing the application software and/or translating device capable of integrating three or more diversely different analyses together with a widely used, commercially available CAD station and demonstrate the integration on a Government-approved computer system. The plan shall specify the approach, intermediate products for review, the required inputs, and the expected results as well as the conditions of the final demonstration. The plan shall also include formal provisions for regular interaction with the developer(s) of Tasks 2 and 3.

(g) With Government approval of the plan in Subtask 1f, the necessary software/translating device for implementing the plan shall be developed.

(h) Prepare and deliver the software/translation device and a users' manual for utilizing the application software and/or translation device. The software/translator and manual shall be of sufficient detail to permit their application in the design of a typical device as chosen in Subtask 1a.

## Task 2. Fundamental R&D

The objective of Task 2 is to conduct long-term research in the following areas:

- The improvement of the computer-assisting techniques associated with reliability, maintainability, and supportability analysis.
- The development of methodologies to evaluate and validate the techniques developed under this task as well as those employed in Task 1. Task 2 at a minimum consists of the following subtasks:

(a) Select one area of research from electronics, mechanical, or structural engineering disciplines.

(b) Define a proposed methodology to assist the engineer in optimizing among competing design requirements (i.e., performance, reliability, maintainability, supportability, cost, and schedule). All levels of assembly from the lowest subassembly level to the entire weapon system shall be addressed.

(c) Identify those areas of design analysis technologies within the RM&S disciplines which require improvement or new developments to accomplish Subtask 2b.

(d) Define proposed evaluation/validation techniques (benchmarks) for the techniques identified/developed in Subtask 2b.

(e) Develop a research plan detailing potential solutions to a subset of the problems identified in Subtasks 2b-d, and a method for achieving them within the scope of the anticipated funding. The plan shall also include formal provisions for regular interactions with the developer(s) of Tasks 1 and 3.

(f) Upon Government approval of the plan, develop the prototype techniques identified in the plan.

**Task 3. RAMCAD Engineering Curricula**

The objective of Task 3 is to develop engineering curricula that address the use of RAMCAD in a computer-aided design process. Task 3 as a minimum consists of the following subtasks.

(a) Establish a series of workshops with a representative cross section of engineering universities and the developer(s) of Tasks 1 and 2 to obtain and document suggestions for the curricula development and implementation.

(b) Prepare a plan for the development of the curricula to address all of the design disciplines of electronic, mechanical, and structural design.

(c) Upon ratification by the university workshop members of Subtask 3a, and approval by the Government, prepare prototype curricula. The technical proposal must include an outline and full discussion of the nature and scope of the research, the method or technical approach, and the expected results. Also include a description of available facilities and resumes of personnel who will be participating in the effort. The accompanying cost proposal/price breakdown should be supplied on SF1411, together with supporting detailed cost schedule. Proposals must reference the above number.

## (2) DELIVERABLE ITEMS

The following deliverable items are required: The contractor shall deliver:

(a) R&D Status Report, DI-A-3002 (monthly)

(b) Performance and Cost Report, DI-F-1208A (monthly)

(d) Cost/Schedule Status Report, DI-F-6010A (quarterly)

(e) Contract Work Breakdown Structure, DI-A-3023

(f) Detailed Research Plan, DI-S-30595

(g) Interim Report on Research and Development, DI-A-5023 (as required)

(h) Final Technical Report, DI-S-3591A (draft and reproducible final)

(i) Computer Software Product, DI-H-5545 (as required)

(j) Computer Software/Computer Program Data Base Configuration Item(s), DI-E-30145 (as required)

(k) Abstract of New Technology, DI-A-3028B.

## (3) TOTAL CONTRACT PERIOD ANTICIPATED

45 months of technical effort plus four months to process the final report.

## (4) EXPECTED AWARD DATE

Between 1 June 1986 and 1 September 1986

## (5) GOVERNMENT ESTIMATE

Minimum of 42.5 man years of effort

## (6) TYPE OF CONTRACT

Cost Plus Fixed Fee with a maximum cost of $3M

## (7) GOVERNMENT FURNISHED PROPERTY

None

## (8) SECURITY REQUIREMENTS

It is anticipated that all work performed under this contract will be unclassified

## (9) SIZE STATUS: See Note No. 11.

Firms responding should indicate whether they are Small Business or a Certified 8(a) Business

## (10) NOTICE TO FOREIGN AND FOREIGN-OWNED FIRMS

Such firms are asked to immediately notify the Air Force contact point cited below upon making a decision to respond to this announcement. This action is necessary to begin review and clearance procedures. Such firms may elect to await the determination before incurring costs in proposal preparation

## (11) PRDA CONTACT POINTS

Questions on technical issues may be referred to the project engineer, Air Force Human Resources Laboratory, Logistics and Human Factors Division, AFHRL/LRA, Attention: Capt. Lois Clutter, Wright-Patterson AFB, OH 45433-6503, (513) 255-3871. Questions on contractual/cost issues should be directed to: Directorate of R&D Contracting, ASD/PMRSC, Attention: John M. Lipker, Wright-Patterson AFB, OH 45433-6503, (513) 255-5633. All questions must be submitted in writing within 12 days of date of publication of this announcement.

# Appendix B

# INSTITUTE FOR DEFENSE ANALYSES COMMENTS ON GENERAL DYNAMICS MONTHLY REPORTS

## (UNEDITED)

The following are review comments made by IDA and provide a history of the progress and a picture of the current status of the GD program.

## A. JULY 1987 TO AUGUST 1989

### 1. July 6 to September 30, 1987 - Initial Efforts

A kick-off meeting was held in San Diego on July 6, 1987. The General Dynamics (GD) team is focusing on three key areas:

(1) The Design Process as seen from a Convair perspective. Their first task will be attempting to determine how the Convair process works. One of the models is a business model prepared by their Integrated Resource Management (IRM) group. Fortunately, they are establishing contacts within the engineering groups to try to get the designers' perspective.

(2) A Software Survey of potential suppliers of programs that might be used in the RAMCAD prototype.

(3) The RAMCAD System Concept. This is a misnomer as they are really focusing on the hardware; and any real system considerations will have to include the software survey results. They should recognize that the software, not the computer experts, will define the hardware platform.

The GD RAMCAD contract was finally signed on September 14 so the above work was really preliminary in nature.

## 2. October 1987 - Monthly Status Report

The October 1987 monthly status report reviews the three areas described above:

(1) Design Process Simulation

An ambitious survey form has been completed that covers three primary areas: what is the design philosophy at Convair, how does an engineer determine trade-offs, and where in the design process is consideration given to RM&S issues. We may find that this effort is attempting to acquire too much information at one time. The same group that will receive the survey was involved in a study done last year. A review should be made of how the information gained last year turned out after a year of reflection.

GD plans to review these new survey responses with the knowledge gained from their study of other "classical" design processes. However, it is not clear how this study will be used to check the survey results. What are the criteria for comparison?

(2) RM&S Software Survey

A multilevel screening process of vendors is under way. This should reduce some of the review time. It would be interesting to see and understand how their "checklist" was developed.

(3) RAMCAD System Concept

A second kickoff meeting (now that the contract was signed) was held in San Diego with only the Air Force, Army, and GD in attendance. The monthly report reflected the key issues that arose:

> What should the hardware be for RAMCAD? It now appears that the hardware equipment selections will be largely determined by what systems are to receive the product at Wright-Patterson Air Force Base and at Picatinny. The software may thus have a secondary influence. This is all right for a prototype system but what about the next iteration of the RAMCAD system? Shouldn't we look at the future implications of the current decisions?
>
> We concur with their strong support for Unix and X-windows. Both of these will be in use by the majority of systems in the government in the near future.

## 3. November 1987 Status Report

(1) Design Process Simulation

Is progressing with the added benefit of interviews with engineers.

(2) Software Survey

No comments.

(3) RAMCAD System Concept

Work is progressing in the technical considerations for a prototype system. There needs to be more thought as to its purpose and the human interface. The survey will help both of these areas. However, it appears the results of the survey will be finished at the same time as the advanced prototype system design. The system design needs the results of the software survey and the engineers' inputs to become a true RAMCAD system.

## 4. November 17 Trip to General Dynamics, San Diego

Watts Hill attended the last half of the GD RAMCAD staff meeting. He discussed the RAMCAD concept and its history that brought us to the PRDA announcement. This was helpful to the GD team as most were new to RAMCAD and not part of the technical proposal team. There has been a lot of progress in the two years since the PRDA was conceived.

Watts then worked with Hal Pal on methods to develop a microplanner schedule for the GD program. Unfortunately, the key goal of this effort is not being done correctly, because all participants must have input into the development of a schedule and the dependencies associated with their tasks. Hal is attempting to develop a schedule based on his personal experience and the contract milestones. This will give us a graphical picture of the GD program and the tasks and their dependencies. Unfortunately, it will not be truly representative of the actual GD program.

## 5. December 1987 Status Report

(1) Design Process Simulation

Two key points are brought out in this month's report:

1. The problem of how to represent the information gathered in their survey and interviews with engineers.
2. The need to diagram Convair's Individual Design groups and their interactions.

Point 1 is an understandable problem given the size and scope of the three areas they were attempting to address in one survey. Hindsight would suggest that more work and thought applied to the creation of the questionnaire, and into how to use the information, would have reduced the size of this problem to a manageable level.

(2) RM&S Software Survey

Again, we see the concern with the volume of data collected and how best to represent it. This problem, while it is not trivial, would be more easily dealt with if the data needs and their use were defined before the survey was developed. Perhaps they are finding it difficult due to a lack of knowledge of what they want out of the data. GD states that Repair Level Analysis (RLA) and Electronics Reliability, Availability, and Maintainability Simulation (ERAMS) are both in the public domain now but we are not aware that this is the case. Suggest they check this again.

(3) RAMCAD System Concept

Again, there is concern over designing the prototype before analyses of the engineers' design process and the software survey are completed. The process should be to determine the users' needs, find the software programs to meet these needs, and then determine the hardware to meet the software needs.

The consideration of using Oracle or Informix as the data base shows some good forethought. Both data bases are based on the SQL language, which allows for the substitution of either one and is clearly, in the near future, the best data base query language for most systems, large or small. As to the question, is it the way for RAMCAD to go, we don't know enough about RAMCAD needs to decide that now.

This month's report also shows that they are getting more specific with respect to the modules they want to incorporate in their prototype. Looking at different software modules can be productive at this point in order to begin to identify what sort of interfacing requirements may have to be addressed once the final decision is made on the specific modules.

## 6. January 1988 - Status Report

(1) Design Process Simulation

The issue of combining mechanical, electrical, and structural sections in their design process is not being addressed: one should note that they are currently only addressing the question of combining, not the key issue of integration. Perhaps the most important aspect to this work is the identification of the different "ilities" that each discipline addresses and the lack of commonalty among them. Since the mechanical and structural disciplines traditionally design to "safety factor" and "infinite" life for a given stress criteria, instead of reliability per se, the need to look beyond the advertised Reliability, Maintainability, and Supportability (RM&S) software field has arisen. This problem will have to be studied and dealt with in any RAMCAD development which deals with more than just electrical design, as does GD's.

(2) Software Survey

Software Survey Selection Form. This form needs a great deal of explanation concerning the actual questions being addressed and their purpose.

The rating system is unknown. How are they scoring these questions and how is each weighed?

(3) RAMCAD System Concept

Informix has been picked as the data base for the prototype RAMCAD. At the SDR it will be interesting to hear why Informix was chosen over Oracle. Both have excellent reputations. Oracle appears to be more transportable among different makes of computer systems. Perhaps the ability to customize the user interface was a strong influence.

GD is also developing baselines for program output in order to test for valid data when a combination of programs are used within RAMCAD.

The basic concept for the system design is desirable, but how acceptable it will be for the user will determine the value of the system. At this point of the system design, we should be researching the user interface requirements. If the interface is not done correctly, the software can be excellent and the system won't be used.

Their statement about IGES suggests to us that they should look at IGES capabilities. IGES deals with the key question of how to move information among programs.

RAMCAD Advanced Prototype Data Flow diagram

This is very confusing, since it is hard to tell how the system interaction takes place.

## 7. February 1988 Status Report

(1) Design Process Simulation

When reviewing Mechanical Advantage by Cognition, were any of the team members from GD Mechanical Engineers present?

Another question for Cognition for their Expert Cost and Manufacturing Guide is, "Can it take into account an individual company's specific manufacturing processes and cost?" Most manufacturing cost packages assume a process and the costs associated with that process. Thus, you can find it useful only for comparison purposes in relation to the software programs manufacturing process.

(2) Software Survey

No comments.

(3) RAMCAD System Concept

A very important problem in relation to RAMCAD was presented here, that of sufficient data on the electrical parts to allow modeling.

The problem is the age and lack of information. If a designer is working with current components such as integrated circuits, they must have the necessary electrical information to be able to properly integrate into the design. The example they referenced was for a 555. This is called an electronic timer, one of the most common integrated circuits in production today. It has been in production for ten years and is manufactured by at least three different manufacturers. If an integrated circuit that is so common as this is not modeled, then the systems like Mentor Graphic are useless. It's like having a new car with no engine and you have to research the engine and put it in the car yourself. Next you find that there are no wheels and you have to research and install these. This goes on until the car is complete. In the future, if all your changes to the car design always use exactly the same parts, okay, but if a new tire comes out, you again have the same problem.

## 8. March 1988 Progress Report

(1) RAMCAD System Concept

More detailed work is progressing on the advanced prototype with discussion about how the modules will talk to each other. There is also discussion about the "human factors" aspect of the system. This needs to be examined and should be a critical part of the system review. However, they state that they are going to use some of the same people they interviewed and, more specifically, Avionic Engineers. Is this the best sample set? Perhaps not. The RAMCAD system is comprised of three disciplines, Electronic, Mechanical, and Structural. Why shouldn't the reviewers be from these disciplines, not just Avionics. Also, we learned at SRR that the engineers who were involved in the survey were mostly managers. What about the engineer on the line doing design on a daily basis, not just reviewing other's work? In short, the reviewers should be more diverse in their backgrounds and not just those who were interviewed.

The discussion as to what will be the "figures-of-merit" remains open.

## 9. April 1988 Progress Report

(1) RAMCAD System Concept

The discussion of 2167 continues as GD attempts to develop a tailored version. The review of the tailored version (delivery in June to Air Force and Army) and its acceptance and review will have a major impact on this program's progress. We need to keep in mind that this is to be used as a guide to ensure sufficient information to allow others to learn from the work done at GD. It appears that 2167 requirements were added out of naivety on the part of the contract officer, not by originators of the PRDA itself. There is a lot of debate against 2167, particularly about the rigid application of it to research programs.

## 10. May 1988 - RAMCAD System Concept

The 2167 requirements still appear to be taking up a major amount of their time. In talking with them, it appears that contract language and the CDRLs are not in sync as to what they must do to satisfy the contractual requirements. The CDRLs are less flexible as to the tailoring of 2167. The Army and Air Force will need to look at this with General Dynamics to help ensure resources are not wasted. The formal software price matrix discussed has not been delivered to IDA, and we assume it is only for contract purposes.

In reference to the networking software received, it appears all went well. I am sure there were problems in installing the software/hardware. The lessons learned here may be directly usable by the Army and Air Force. These need to be documented.

In their discussion in reference to M-Spice, we assume the main effort of work described was again due to a lack of electronic parts in the Mentor library.

## 11. June 1988 - RAMCAD System Concept

The data base is growing as it now will contain both the inputs given to an analysis program and the results produced when those inputs are acted on. An interesting question now would be "How long will this information be stored and how often will it be updated?" As an example, an engineer makes minor changes many times while trying to optimize a design. Will it save all the different inputs/outputs or only the final one, or the last three, or etc.?

The work on the user interface is now focusing on the question, how to make it more "user friendly," but where are the discussions as to user needs! Also, if we are concerned with user acceptance (a more accurate way of saying "user friendly"), what about an industrial psychiatrist. The folks working in cockpit design may offer some relevant suggestions.

Under the paragraph describing what software "has been exercised and/or validated": let's not forget that Eagle Technology's Mechrel is a demo only and not a functioning software tool.

The analysis done on the other packages by GD should be documented. The lessons learned here are important today.

## 12. July 1988 - General Dynamics Review

(1) RAMCAD System Concept

The PDR preparation has consumed the team's time this month.

However, the work on the advanced prototype should be noted. Time is being spent validating the outputs of the software. This is critical to ensure acceptance by designers. Any designer's attitude when they first work with RAMCAD will not be one of comfort for two primary reasons. First, any method that differs from the way they do their work now will be viewed with some misgivings, even if they are now using computer-aided tools (if they are not using any computer-based tools, these feelings can be very strong). Second, there will be a reluctance to trust the system's computations, as this system will appear to produce results on its own. The engineer will not be manually controlling the inputs and calculations. One incorrect calculation will cause the engineer to dismiss the RAMCAD system's usefulness.

(2) Program Management

No comment

(3) Special Programs/Equipment Purchases/Constructed

We would be interested in finding out if the team knows why DOS would not operate under Xenix or the 386 PC. As usual, the manufacturers of the equipment tell the world that all works perfectly.

In discussions with Bill Dawson, we understood that AIX (the IBM implementation of Unix) was very buggy. This would be perhaps acceptable for the prototype, but what about the actual system?

(4) Appendix A - Lessons Learned

An excellent addition to the report, this new section really meets the objective of RAMCAD. This month's section reflects normal development events and clearly shows progress.

## 13. August 1988 - RAMCAD System Concept

See comments under SDR review.

(1) Program Management

The expiration dates for the software on loan to GD are before the projected time for the contract modifications to be put on the contract. GD could very well be looking at a stoppage of their work if this is not resolved.

GD commented that they will report to the government in September as to the status for extensions on the loans after the expiration point for some of the software.

(2) Lessons Learned Problem Summary

B. We concur with the government's request to use Oracle due to the fact that it is already in use by the sponsors and that it is an SQL-based data base as was Informix.

D. We hope this additional management support of GD will lead to use of RAMCAD within GD. This is one of the RAMCAD program goals.

## 14. September 1988 - RAMCAD System Concept

Again, we see a major limiting factor in being able to use CAD tools--the lack of component information. The power switching amplifier has 499 components in it. Most of the needed information on each was in a paper form, which will require manual entry. It appears that for a company to have an electronic CAD or CAE system, one will need to have at least one full-time person just to keep up the data base.

(1) Lessons Learned Problem Summary

The discussion about the lack of electrical component information should be noted. The ability to get the information from other data bases interactively and not having to reenter it is logical. The hardest part will be knowing when to retrieve this in a manner that is timely (when the designer needs it) and with a minimum amount of delay. The closer working relationship between government and industry will only have a chance of working when industry resolves its disputes, in reference to their technical information being in many printed forms.

GD's realization that Mechrel is only a demo is accurate and one that IDA has stated before to the government. For the prototype which will hopefully demonstrate proof of concept, it's fine. But its usefulness for a functioning RAMCAD system is in serious doubt.

# B. SEPTEMBER 1988 TO SEPTEMBER 1989

## 1. January 1989 - RAMCAD System Concept

As work continues, we are encouraged by the progress reported and the understanding of the need to perform manual checks on the automated system.

The Mechrel program still plays a key part in the mechanical design. As this is a demonstration piece of software, we still need to fill this void.

## 2. February 1989

The main progress this month deals with the presentation of the program at PDR.

A draft of most of this material was received by IDA, HRL, and Picatinny for their comments and review. Most of the issues raised have been addressed at the PDR level and are being updated or corrected.

The most significant point raised is that GD's work has now progressed to the point that the intent of the original PRDA has been demonstrated--that of using diversely different "off-the-shelf" commercial software in a single engineering environment.

### 3. March 1989

Work continues on the integration of the comments and direction given at the PDR. Work is also progressing on the draft of the software requirements specifications.

### 4. April 1989

Since Mentor Graphics has discontinued support of the M-Spice Plus (circuit simulation tool) which was used in the advance prototype, ACCUSIM has been added to replace it. We should document in lessons learned the problems and methods used to convert the data files as there may be others in the future who will have a need to do so.

The discussion of integrating RAMCAD into the GD internal program of Integrated Manufacturing System (IMS) is most encouraging. The GD program has always needed more user input from the engineering departments.

### 5. May 1989

A great deal of time and work has gone into the software requirements specifications. GD has put a large amount of work, organization, and detail in the draft of the SRS (final release was due on 15 June 1989).

### 6. June 1989

The training that is being performed by GD should be observed by the programmers responsible for the user interface. Careful notes should be taken as to any distractions and/or problems noted by the users. New users have the advantage of trying things on the system in the way they perceive they should logically work.

## C. MILESTONE REVIEWS

### 1. Systems Requirements Review (SRR)

On March 15-16, 1988, the Air Force, Army, and IDA attended the SRR at General Dynamics. This was the first major milestone in the GD RAMCAD program.

The Review covered four primary areas, Design Process Simulation, Reliability, Maintainability and Supportability Software Survey, and the RAMCAD System Concept and Project Management.

The first of these areas (Design Process Simulation) was to determine how or what process is used by designers at GD to create a new design. This was believed to be necessary because one cannot improve upon a process unless one knows how the work is conducted. This was accomplished by GD interviewing 73 engineers from 18 different design groups. A large number of the designers were supervisors. As a result of this, the government recommended that the number of day-to-day designers be increased to ensure the results represented the *current* GD process.

After this survey the team looked for a common figure of merit to allow trade-off considerations to be done between different design disciplines (electrical, mechanical, and structural). Their recommendations were to use mean time between failure (MTBF) to measure reliability, mean time to repair (MTTR) to measure maintainability, and operations and support (O&S) cost with repair-level determination to assess supportability.

This approach has raised many questions, in part because the government has found that MTBF is a term/concept that is not acceptable to the mechanical engineering community. The concept of integrating the three disciplines is critical if RAMCAD is to progress beyond being a "design checking" tool.

**RM&S Software Survey**

A survey of RM&S computer programs available on the commercial market was performed. Those programs considered in the survey must be currently available to anyone who wishes to purchase them. Government-owned or -sponsored packages were considered if they were generally available. (RAMCAD was to allow industry to change the way they design products, thus yielding better systems to the government.) The software survey team reviewed 153 software packages and documented their findings. The following programs were selected, in some cases because they were the best and in others because there was no other choice.

(1) RelPlus from Prophet Software (Electronic Reliability)

(2) Mechrel from Eagle Technology (Mechanical Reliability, 217D)

(3) I-Deas from SDRC (Structural Reliability)

(4) MPP from Powertronics Systems (EM&S Reliability)

(5) NRLA from AF Acquisition Logistics Center (EM&S Supportability).

Mechanical Advantages planned improvements may allow it to be supplemented if Mechrel does not materialize.

The major conclusion from this survey is the *lack* of good software tools for the mechanical engineering community. This task in their contract will be continued throughout the contract.

**System Concept**

This was the preliminary idea for the RAMCAD system. The primary focus was from a programmer's perspective, i.e., on the computers and the operating systems that may be used in the prototype. The focus is still on integrating the three disciplines, mechanical, structural, and electrical. At this point it appears that Unix with X-Windows will be the operating system. This will help ensure the ability to move from one hardware platform to another.

**Program Management**

This final part of the SRR addressed items of a contractual nature only.

## 2. System Design Review (SDR)

The SDR was held on August 10-11, 1988.

After the review of the materials presented at SDR and the discussions that took place we have noted a list of issues that still needs to be addressed.

Concerns for SDR (System Design Review)

- "General System Architecture"

  Reflects the basic General Dynamics approach. Three standalone "RAMCAD" systems with limited interaction among the three. The primary interaction among the three is the users' interface. All three share the data file, sometimes using the translators for interpretation and formatting of the data.

- System Design Review: Advanced Prototype Software

  Third paragraph down reinforces our concern as to the degree of engineering input. When a designer is specifying a component such as a resistor he does not normally worry about wattage when he or she is deciding on a value for it.

Their focus is getting the schematic in their head on paper or screen and looking to see if the circuit will function. The computations for wattage are done after the fact and usually by someone other than the designer (junior engineer or senior draftsman) unless the component size is critical. Even then it is usually checked by the designer after someone else has done the calculations.

- Heavy emphasis on solid modeling

  We have reservations about the importance and the priority placed on this. Are we letting the "oo's" and "aa's" of graphics get in the way of our objectives?

- Is "mechanical advantage" the best package to be using?

  As this is a package still under development at Fort Belvoir, Virginia, are we aware of how their proposed changes will affect the usefulness of this software in the future?

- In a constantly changing environment of hardware and software, what plan do they proposed to ensure our awareness and theirs as to what is happening in industry and the government? Aren't they supposed to be tracking this and reporting back to us on what they are finding? It has been more than half a year since their original study was done; a great deal has happened, and yet we have received no information.

- Data Base Management System

  We are glad to see their emphasis on SOL as it comes as close as anything else to a common data base language. Informix is clearly one of the "major" data bases for serious data needs. As to the question of Informix versus others, such as Oracle (which as just been released for the IBM and Mac systems), we find that programmers tend to have a love-hate relationship with the programs. If it is the one they use and know they believe it to be best, and the others tend to have "problems" in their mind. The rationale for choice seems the best given their imposed restraints. If new data bases come out which prove to be better, they could transition to another SQL-based data base when it makes sense.

- Display on the Workstation

  There appears to be a lack of inputs from multiple users of the workstation and the process of its development. The most noticeable is the same mistake TRW made in their system--the display was designed by the programmer, not the user! The letters and words, for example, are too small for the average user. This is the classic mistake most programmers make on large display screens. One tends to focus on the larger display area that is available for information display and gets caught up in displaying as much information as they can squeeze into the area.

Two factors need to be considered here. One is how much information can one individual work with comfortably on any screen at one time and yet not be distracted by more. The second is fatigue; the display on a color screen due to the physics involved is not as clear as the same size screen on black and white, thus the information displayed must be constructed to reduce fatigue. Techniques such as larger letters, contrasting colors, limited number of colors (the natural tendency is to "make it as spectacular as possible" with 256 colors), and consistency of color to meaning are some of the factors to be considered. The displaying of information in a manner to maximize the information being communicated is itself a science.

- The use of MTBF for structural analysis

  The structural community and some academics of this discipline have all expressed their concerns with MTBF being applied to the physics of failure of materials. Are we perhaps using this as an easy means of communications among software packages and avoiding the more difficult problems of failure analysis?

- The electronic R&M analysis station is totally based on 217 analysis techniques. These techniques are under some attack when applied to complex assemblies, and a different approach may well be developed in the next few years. Provisions should be made for utilizing other techniques as they appear.

  The mechanical and structural R&M analyses are partly dependent on analysis techniques that do not have general acceptance in the mechanical/structural design field. Here also provisions should be made for incorporating other techniques as may be decided later.

- The contract specifies using commercially available software without any alterations. This limits the ability to make interactive trade-offs which are required for a design tool vis-a-vis an R&M analysis tool. For example, trading thermal placement requirements with routing placement requirements is a long-winded iterative process if the only way to do it is to run a complete thermal analysis, then a complete routing analysis repetitively. To optimize the interaction would appear to require tampering with the source code which is prohibited by the contract even if the vendor gave permission. There may, therefore, be technical limitations in trying to make a design tool out of unaltered R&M analysis packages.

## 3. Preliminary Design Review (PDR)

### a. Overview

The Preliminary Design Review (PDR) represents a major milestone in the research and development of the RAMCAD system. It was held on February 22-23, 1989, at General Dynamics. Approval of the preliminary design releases General Dynamics to move forward with their concept for the development of a fully functional system.

The functional system is based on the prototype system discussed and demonstrated at the System Design Review (SDR).

The functional system will be based on the use of computers produced by Apollo, IBM, and Digital Equipment Corporation. These systems will be able to communicate and exchange information via a network based on Ethernet. The ability to exchange data is a necessity for the different programs to be able to use the work accomplished by the other programs. The central storage for this information will be developed around a data base system called Oracle. Oracle will store the information necessary for the modules, called translators, developed by General Dynamics. These translators do just what the name implies. They translate the information from a generic format for the data in Oracle to the specific format needed by the program requesting the information. These translators are bidirectional, thus allowing new information to be stored in the master data base. All of the design tools, both commercial and those developed by General Dynamics, are able to utilize the information stored in the master data base, either directly or with the assistance of translators.

The data base also controls the access to each of the commercial software programs through its user interface. This is done for two reasons: (1) to give the user a common reference point for accessing each package of software on the system; and (2) to ensure that the computer system knows exactly where the user is and what they want to do. By requiring that the user go through this common point, the system retains control whenever the user goes into the system. Thus, it will allow the RAMCAD system designers to ensure such things as the correct translator being in place when it is necessary. Control on the General Dynamics' system by a central master program will allow the user, in the future, to insert new or better software into RAMCAD for use by its designers.

### b. IDA Review of PDR Presentations

The basic system concept as proposed was accepted at the SDR and now the details of the actual approach must be dealt with at PDR. Our major concern was with the lack of data for the physical, mechanical, and electronic components. This information can be found in printed form but not necessarily in an electronic format. The other half of this problem, if the data were to be made available by the manufacturers of the particular component, is "what information is needed and in what format?"

Each piece of software to be used to assist a designer has specific information needs. Some of this information, such as that which needs to be calculated, can be done by the RAMCAD system through the translators, but these calculations require certain information. This problem has been with us for years--that of what form and format this data should be in. IDA addresses this issue in a report on the competing standards being proposed to attempt to solve this problem. There is still no single solution to this today.

The first half of this problem is the reluctance of manufacturers to release this information. As an example, in the integrated circuits manufacturing market there are hundreds of books published each year by the various manufacturers and others on the specifications for their integrated circuits. There have also been hundreds of thousands of different integrated circuits produced. Consequently, the volume of information is staggering. Programs such as CALS are testing this very problem, with the massive amount of information that is generated, to attempt to put it in a common form that in the future will allow rapid access and still be current information.

How does a company such as Valid or Mentor Graphics handle this for their electrical design system customers that require this type of information? They allow the customer to research the information on a component-by-component basis, and manually enter it into their systems data base in their own form and format. This information is usually obtained through a parts specification catalog published by the original manufacturer of the integrated circuit.

There has been some progress in this area as a small number of companies are entering information on the more commonly used integrated circuits into each manufacturer's data base, and reselling their labor for owners of such systems to use. The most common solution for owners of these design systems is to hire an individual who is responsible for the maintenance and updates to the designer's system. As a result, the systems tend to contain information on components used on past designs. Thus, an engineer will be forced to do the conceptual and some preliminary design in their mind with new components. Only after the design is fixed in their minds will they test their concept on the system after the data on the new components is entered.

This is a problem to be addressed and highlighted by the RAMCAD program but is not within its scope to attempt to solve. [Reference--ML Brei's paper on "Data Exchange Standards."]

Our next concern is with the lack of commercially available software for the mechanical engineers to use in their analysis work. If we look at the current RAMCAD program we see software such as Mechrel Plus being used to fulfill a particular need. Yet we are aware that this is only a demonstration program and the calculations which are introduced by Mechrel Plus are in error. Mechanical reliability has not been addressed by the commercial and computer industry as thoroughly as has the area of electronic design. GD is attempting to bring before the designer information on the electrical, structural, and mechanical aspects of their active designs. This requires a balanced view, but a balanced view is not possible if the analysis tools are not available.

Another important issue is the User Interface. When we observe the actual computer screen and the way it would be operated by a designer (user interface), we note a lack of commonality with the computer industry and its approach. We believe that GD needs to do more research into the design of user interfaces and that they also need more input from the design community that would use such a system within GD. We are speaking of the actual day-to-day users, not the supervisors or managers. If the user does not accept the presentation method for the information relating to their design or if they find it tiring, they will not use the system. The user interface is as critical as the software programs performing the analysis.

Our last concern is with the problem of how to go about the integration of the mechanical, structural, and electrical aspects. By integration, we mean the ability to see the effect of a change made in one discipline upon the others. It is critical for the full development of a RAMCAD system that this issue be addressed. If we ignore the issue of being able to make trade-offs among the different disciplines, then we end up with a fancy system for design checking.

### c. Summary Comments on the PDR

It appears that what General Dynamics has developed is a workstation that enables an R&M engineer to do his work more rapidly. This accomplishes one goal of RAMCAD, i.e., to reduce the turnaround time for R&M analysis of designs from two to three weeks to a few minutes (given a tie-in to the CAD system).

To satisfy the rest of the Task I goals, this could be made into a design tool (i.e., actually become a part of the CAD process used by designers) if more attention was paid to the executive controller and the man/machine interface in order to satisfy the designer's needs. To date, the designer's input has been minimal, and designers need to be more directly involved in the RAMCAD development process. (An approach such as TRW's rapid prototype might be useful.)

General Dynamics has an electronic system R&M analysis station demonstration and the detailed plans for mechanical and structural R&M analysis stations. Thus, the goals of Task I have been shown to be attainable and have been partly achieved.

It is our position that the PRDA was never intended to be carried out as separate tasks by separate contractors. Task I was intended to be a rapid demonstration of what could be done to tie R&M analysis into the design process using commercially available hardware and software. This demo was felt to be necessary in order to provide a baseline and momentum for Task II, which would address the question of using advanced technology and advanced ideas from lessons learned in Task I. This was done in order to attack the fundamental problem of integrating R&M requirements and analysis into all phases of design.

The next phase of General Dynamics development work will start to address some of the issues for Task II.

# Appendix C

# INITIAL CALS IMPLEMENTATION PLAN

# EXECUTIVE SUMMARY

## A. THE TASK FORCE CHARTER

In April 1974 Under Secretary of Defense DeLauer and Assistant Secretary of Defense Korb issued a memorandum which tasked the Institute for Defense Analyses (IDA) to assemble a task force of senior industry and government logisticians to address the problems faced by DoD in applying new and emerging computer technology to improve the logistics support process. The task force was given a charter to "develop a strategy and a recommended master plan for computer-aided logistic support." The task force was formed and held an intensive series of meetings throughout the last half of 1984, during which time this report was prepared.

The DeLauer/Korb instruction was generated by a perception in OSD that there was an important opportunity to coordinate the rapidly expanding automation of support functions in the Services and the Defense Logistics Agency with the efforts in segments of the defense industry to achieve "near-paperless" design, engineering, manufacturing, and logistics planning operations. Through integration of automated reliability and maintainability analysis into initial computer-aided design, better supportable weapon systems can be designed and manufactured. There are also enormous potential benefits in logistics efficiency if the product definition and technical data which manufacturers generate in digital form could flow to all users in the support system without the hardcopy paper links that are now used to transmit information. The CALS Task Force confirmed these perceptions, and developed program objectives and a strategy to take advantage of this opportunity.

## B. CALS PROGRAM OBJECTIVES

Working in cooperation with the defense industry, other government agencies, and professional and industrial associations, the Department of Defense should take immediate, positive action making use of current and emerging computer technology to:

- Design more supportable weapon systems.
- Transition from paper-based to digital logistics and technical information.
- Routinely acquire and distribute logistics and technical information in digital form for new weapon systems.

These objectives cannot be achieved immediately. But by following a strategy of near-term, mid-term, and long-term actions, DoD can, within five years, have in place a program for receipt and distribution of logistics products in digital form for all major weapon systems entering production. By taking immediate action at the DoD level to define and adopt a complete set of data exchange standards, and to develop overall architectural guidelines for automation of technical information throughout the Military Departments, DoD can establish the unified interface requirements which will enable industry to accelerate its own automation initiatives. The Military Services already have programs in being that represent important building blocks in this effort; these programs should be strengthened and extended. Service implementation plans should be developed to integrate these individual building blocks into a complete network for digital distribution, processing, and use of the logistics information delivered by industry.

In parallel with these actions to automate the development and distribution of logistic support products, DoD and industry should both take aggressive action to better use computer technology to improve weapon system supportability by integrating reliability and maintainability (R&M) analysis into the initial design process. This is also a central thrust of logistics support analysis (LSA), and a CALS program will provide improved tools for accomplishing LSA objectives. Industry has the principal responsibility for incorporating these automated analysis tools into its computer-aided design and engineering (CAD/CAE) processes. However, DoD must provide the design requirements and contract incentives needed to guide industry efforts. R&D and IR&D priority must be given to meeting this objective.

The strategy recommended by the CALS Task Force provides a phased program of individual initiatives designed to support achieving these CALS objectives. By fully and formally committing DoD to these objectives, and the strategy for accomplishing them, the

OSD sponsors of this study can inaugurate significant and far-reaching improvements in the acquisition and logistics management of future defense programs.

## C. RECOMMENDED STRATEGY AND IMPLEMENTATION MANAGEMENT

The Task Force recommends that a DoD policy be established that will both direct and encourage the integration of existing "islands of automation" and facilitate the transition of logistics processes within DoD and industry from paper-based to digital mode in an orderly way. The policy should stress the need for each DoD component to develop a phased plan for:

- Demonstrations and incentives to integrate R&M into CAE/CAD and to automate supportability design analysis.
- Adoption of DoD-wide interfacing standards and neutral data formats.
- Instituting pilot programs to integrate selected logistics functions into segments of a CALS system, while concurrently requiring that weapon program new starts plan to utilize digital support data.
- Establishing DoD-wide coordination toward a planned CALS architecture.

For each of these thrusts, a plan of action was developed and is presented below.

To implement the planned actions, a management office should be established in each Service and in DLA with responsibility, authority, and resources for coordination of all four thrust areas. While each DoD component should develop a CALS implementation plan that best meets its individual requirements, development of a unified, DoD-wide interface with industry is also needed. There are various options for effecting the necessary overall coordination among the Services and DLA. The Task Force felt that, at the least, a DoD Steering Group should be established at the senior Service level with members from OSD, the Services, and other DoD agencies. This group should be charged with (1) maintaining communication between the individual management offices in each Service and in DLA, (2) maintaining a continuing dialogue with industry regarding CALS plans and programs, (3) overseeing the establishment of interfacing standards and neutral data formats, and (4) evolving an overall CALS architecture. An alternative supported by a portion of the Task Force was an OSD program office with a full-time staff and the funding authority needed to provide more centralized control and direction of the CALS program.

## D. RECOMMENDED PLAN OF ACTION

### 1. Plan for Thrust 1--Integration of Automated R&M and Supportability Analysis into Design

#### a. Findings

- Reliability, maintainability, and supportability (RM&S) analyses are not part of the engineering design mainstream.
- Technology for integrating RM&S into computer-aided design exists.

#### b. Recommended Actions

| | |
|---|---|
| • Formalize inter-Service coordination through a Memorandum of Agreement. | Immediately |
| • Develop new RM&S tools. | Ongoing |
| • Publish plan to expand applications through incentives, contract requirements, and R&D. | September 1985 |
| • Publish catalogue of RM&S tools. | June 1986 |
| • Establish Centers of Excellence for demonstration of integrated supportability design analysis. | January 1986 to January 1989 |

### 2. Plan for Thrust 2--Interfacing Standards and Neutral Data Formats

#### a. Findings

- Interim standards are available and are already being adopted.
- Near-term and long-term DoD goals do not exist.
- Current DoD policies do not support minimum needs for DoD-wide standards.

#### b. Recommended Actions

| | |
|---|---|
| • Establish DoD plan and schedule. | Immediately |
| • Interfacing standards | |
| -- Policy on specific interim standards | July 1985 |
| -- Adopt specific product definition standard. | Summer 1986 |

- Data Standards
  - -- Publish information management and access standard — December 1985
  - -- Publish initial CALS data element dictionary — January 1986
  - -- Publish expanded CALS data element dictionary. — January 1987

## 3. Plan for Thrust 3--Pilot/Demonstration Program

### a. Findings

- Integration of functions introduces need for procedural changes, retraining, and reassignment of personnel.
- Pilot programs are needed to demonstrate the benefits of CALS initiatives in an operational environment and to obtain user feedback for future system design.

### b. Recommended Actions

- Initiate pilot programs to integrate ongoing Service programs and demonstrate: — January 1986 to January 1989
  - -- Digital delivery and use of engineering data
  - -- Automated authoring and updating of technical documentation
  - -- Interactive training and maintenance aids
  - -- Automated LSA data and LSA reports.
- Each Service designate a "lead the force" acquisition program to demonstrate use of digital data from the acquisition cycle through to field use. — 1985 to 1995+
- DoD should coordinate these pilot programs to demonstrate functional use of the specified interfacing standards and neutral data formats.
- All weapons program new starts should plan to utilize digital support data to the maximum extent possible.

## 4. Plan for Thrust 4--DoD-Wide Coordination Toward a Planned CALS Architecture

### a. Findings

- Integration of automated functions requires a plan and management coordination.
- DoD-wide architectural guidelines do not exist.

**b. Recommended Actions**

| | |
|---|---|
| • Issue DoD planning guidelines. | Immediately |
| • Services and DLA publish phased system development plan. | December 1985 |
| • Services and DLA publish initial CALS architecture. | March 1986 |
| • DoD-wide coordination. | June 1986 |
| • Pilot/demonstration programs (see thrust 3). | January 1986 to January 1989 |

## E. CONSOLIDATED SCHEDULE

Figure ES-1 gives a consolidated schedule for the thrusts detailed above. In combination, this strategy will provide at the end of five years all the tools and demonstrated "building blocks" needed to initiate a fully integrated Computer-Aided Logistic Support program for all major and less-than-major systems entering production.

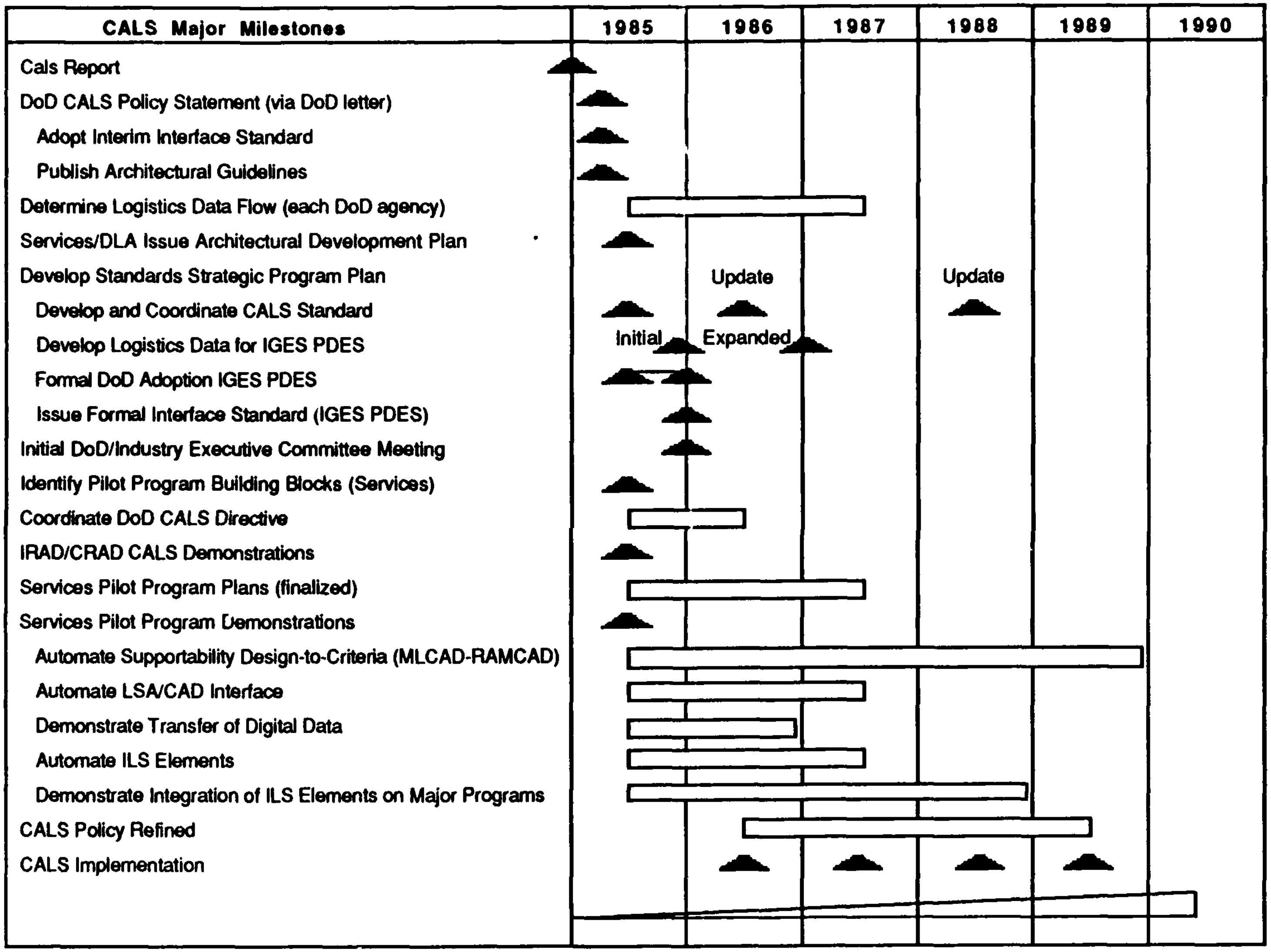


**Figure ES-1. Consolidated Schedule**

# Appendix D

# THE TQM INITIATIVE

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, DC 20301

ACQUISITION

(P&L/PS)

19 AUG 1988

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
ASSISTANT SECRETARY OF DEFENSE (PRODUCTION AND LOGISTICS)
DIRECTORS OF DEFENSE AGENCIES

SUBJECT: Implementation of Total Quality Management in DoD Acquisition

The Department of Defense is facing one of the most challenging periods in its history. We must maintain the important gains in readiness already made and at the same time continue steady improvement in the face of greater austerity, increasing technological complexity, and a growing diversity of threats. We believe that Total Quality Management (TQM) can provide the leverage to meet these unparalleled challenges. I am convinced that by implementing TQM, and by coupling it with the intensified application of such value-added strategies as Acquisition Streamlining, Transition from Development to Production, Could Cost, and others, we can achieve unprecedented improvements in the effectiveness of the DoD acquisition process.

I want TQM applied to the acquisition of defense systems, equipment, supplies, facilities, and services to ensure continuous improvement of products and services being provided to, and by, the Department of Defense. The principles outlined in the March 30, 1988, DoD Posture on Quality will guide TQM implementation efforts. A suggested definition of TQM is shown in attachment 1.

I am making TQM success my primary objective. We will link TQM to the weapon system decision process to ensure that it is properly considered in acquisition strategy development and effectively implemented during contract execution. To this end, I am requesting that the Defense Acquisition Board (DAB) act as the DoD steering group for TQM implementation in acquisition. The initial DAB meeting on TQM implementation will follow the senior level awareness training session scheduled for August 18, 1988. A specific agenda will be forwarded under separate cover.

One of the earliest agenda items will be to approve and issue a DoD implementation strategy for acquisition and identify acquisition improvement objectives. The TQM strategy will serve as a basis for formulation of individual Service and Agency implementation plans. Mr. Jack Strickland, Director for Industrial Productivity and Quality, staff lead for TQM, is developing a "strawman" of the TQM strategy. Copies will be circulated for your review in advance of the initial meeting.

The key to TQM implementation lies in leadership by DoD program managers and by their contractors and suppliers at all tiers. In this regard, management in both government and industry must create the climate which will foster TQM implementation and ensure that their personnel are properly trained and motivated. To initiate this process, I ask that you take the following actions:

1. Develop your plan for TQM implementation. Attachment 2 contains a listing of some preparatory activities that may be taken to start TQM implementation. Your plan should include: (a) how you will incorporate TQM into the acquisition strategies and plans for all major system new starts; (b) how you will apply TQM to existing programs and identify pilot programs; (c) how TQM will flow down to subcontractors and suppliers relating to your programs; and (d) how you plan to apply TQM to those programmatic and other efforts related to the activities of knowledge workers, including management, technical, and other speciality personnel. I would like to review your implementation plan by October 31, 1988.

2. Nominate a SES/Flag level TQM focal point for coordination of TQM at the working level. Your nominee should have a broad perspective of acquisition.

I am looking forward to working with you to help achieve the extraordinary promise of TQM.

Attachments

## Attachment 1

## DoD Total Quality Management (TQM)

TQM is a management process directed at establishing organized continuous process improvement activities, involving everyone in an organization - both white and blue collar personnel - in a totally integrated effort toward improving performance at every level. This improved performance is directed toward satisfying such cross-functional goals as quality, cost, schedule, mission need, and suitability. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools into a disciplined approach focused on continuous process improvement. These activities are ultimately focused on increased user/customer satisfaction.

Attachment 2

## Preparatory Activities for Total Quality Management(TQM) Implementation

To begin the process of TQM implementation, initial steps should be taken to:

- become acutely aware of the principles, practices, techniques and tools associated with TQM (the attached reading list will be useful).

- obtain TQM-related training for key personnel and their subordinates.

- begin a dialogue with development/production contractors and potential offerors to encourage self-initiation of TQM effort.

- examine the programs and processes for which the activity is responsible and identify ways in which to improve them using the TQM principles.

- establish process improvement teams within Government and contractor organizations to pursue improvements aimed at increasing customer satisfaction, improving performance, reducing cycle time, and reducing cost.

- ensure your TQM implementation efforts include improving the processes involving knowledge workers, including management, technical, and other speciality personnel.

- begin TQM organizational planning.

- identify to Program Executive Officers, or Service Acquisition Executives, those contractors who are qualified and receptive to the intensive application of TQM principles.

## Attachment 2 (Continued)

### Suggested Readings

The key to effective and successful implementation of TQM is understanding of the underlying philosophy and theories that support continuous process improvement efforts. DoD and industry personnel need not wait for formal training or indoctrination. The following suggested books are some of the best in the field of continuous process improvement. They will provide a sound basis for understanding DoD's TQM philosophy and vision.

Crosby, Philip B.: Quality is Free, McGraw-Hill Book Company, New York, 1979.

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# Appendix E

# STRUCTURED DECISION MAKING

# STRATEGIC MANAGEMENT AND THE MANAGEMENT OF PARTICIPATION

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## I. *INTRODUCTION*

Strategic management seeks to link strategic planning with decision making and implementation. However, the literature on strategic management, perhaps because it has evolved from strategic planning, does not adequately address the questions associated with decision making and implementation. In general, the strategic management literature has failed to take into account the tools of decision making as developed in the organizational behavior and other literatures. Of particular significance, in our view, is the role that *participation must play in effective decision making processes.* This role is central to effective strategic management, particularly during periods when change is rapid, because it is only through effective participation that decisions can be rapidly communicated and implemented. Unfortunately, the literature on strategic management does little more than pay lip service to the role of participation.

The vast majority of management decisions are either too time urgent or of insufficient importance to warrant full scale participatory decision making. On the other hand, strategic management deals with decisions on which the whole success of the organization depends. Therefore, it is one area of decision making that requires full participation and a careful determination of who should participate in the decisions and how that participation should be managed.

One of the features that most distinguishes the current business environment from that of only 20 years ago is the increased rate of change. A successful planning process must therefore allow an organization to rapidly develop and implement an agreed upon series of actions to meet these changes, and to provide for the continuous revision of that plan as the environment changes. This is particularly difficult because most bureaucracies, large and small, resist change. In fact, when people in an organization say they cannot do anything to respond to a changing situation, what they really mean is that they do not know how to get all the people involved to take the actions necessary to adjust to the situation. It is not so much that people resist doing the right thing, but rather that they don't see how anything can be done without some risk and a lot of effort, thus making them resistant to change. Organizations require management processes that overcome this resistance to change and provide opportunities for people to do the right thing. The careful application of certain participatory management techniques provides a means for doing so.

With these factors in mind, we define strategic management as a continuous process by which an organization identifies a set of long-term objectives, develops a strategy to achieve those objectives, agrees upon a plan to implement the strategy, and sees that the actions called for in the plan are carried out. The key to strategic management is not only the link between a strategic plan and its implementation, which must occur much faster than in years past, but also the need for a decision making system into which important new information is quickly incorporated, resistance to change is overcome, and in which there is a mechanism for following up on the implementation of decisions already taken. To put it another way, planning never ends--it must be imbedded in the management system so that plans may be continuously revised as circumstances dictate.

Strategic management may be seen as consisting of three important features:

(1) *The creation of a documented plan.* A good plan is a necessary centerpiece and reference document, but in itself is not a sufficient condition for the success of a strategic planning process.

(2) *Making strategic planning an integrated part of the management system.* In order to be successful, a strategic plan must eventually be implemented through existing management systems. Plans that are developed by off-line planning staffs or outside consultants frequently fail.

(3) *Properly managing participation in the planning process.* Because the participation of key actors in the organization provides the necessary linkage between the strategic plan as a document and its implementation through the existing management system, it is essential that this participation be properly managed at each step of the planning process.

The next section provides a brief summary of current thinking on strategic planning and management, including a discussion of 10 of the most important attributes of a successful strategic planning, or strategic management, system. Section III begins by asking what a chief executive officer should do if he or she wishes to introduce strategic management into an organization, and then argues that the key to implementing an effective strategic management system is to be found in an understanding of how the CEO should manage participation. Section IV provides some specific techniques, which we call Structured Decision Making, for managing participation in a strategically managed organization.

## II. STRATEGIC PLANNING AND STRATEGIC MANAGEMENT

Strategic planning is most commonly thought of as the development of a formal strategy. Most writers on, and practitioners of, strategic planning devote themselves to the development and exposition of particular strategies or strategic approaches for specific industries or markets. A smaller but still substantial group of authors focuses on the appropriate analytic methods for successful planning--what questions need to be asked and what information needs to be obtained in order to develop a good strategy. The three most prominent planning concepts developed and used during the 1970s were the experience curve, the strategic business unit, and portfolio planning.[1] The 1980s have seen the development of competitive analysis, or what is sometimes referred to as the industry structure model. Here Michael Porter's work on "Competitive Strategy" appears to be seminal.[2]

Organizations use the the strategies and strategic approaches available to them to prepare a plan. Often, however, the strategic planning process proceeds little further than the writing of this plan and its transmission from senior management to the rest of the organization. As is well known, strategic planning developed a bad name for itself in the 1970s precisely because consulting firms (and internal strategic planning staffs) would develop plans that firms were unable to implement. The firms blamed the consultants for writing lousy plans, while the consultants blamed the firms for their inability to implement perfectly good plans. It finally began to dawn on people that not only are implementation issues more complex than originally thought, they are in fact central to the success of any strategic plan. To be successful, the process by which the plan is developed should lead directly to its implementation within existing management systems. Thus we have strategic management, not simply strategic planning.

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1 For an excellent historical review of these planning concepts, see Gluck, Frederick W., "Strategic Management: An Overview," in James R. Gardner, et al., eds., *Handbook of Strategic Planning*, Wiley, 1986, pp. 1.7-1.12.

2 Porter, Michael E., *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, The Free Press, New York, 1980; and *Competitive Advantage: Creating and Sustaining Superior Performance*, The Free Press, New York, 1985.

### Strategic Management

A small group of writers and practitioners have long recognized and addressed the difficulties associated with the implementation of strategic plans. Among them there is widespread agreement on the basic attributes of good strategic management systems. Ten attributes are listed below, but the first three are of particular importance:

1. The strong support and involvement of the CEO is essential.
2. The primary responsibility for developing strategy belongs to those who must implement it, particularly line managers. Their participation and the nature of that participation are of critical importance to decision quality and ownership.
3. The primary role of staff (non-line) elements is to act as facilitators to the planning process; it is not to take control of the process or ownership of the product.

These three attributes constitute the "first principles" of strategic management. Although not everyone adheres consciously to these principles, and although many practitioners pay them little more than lip service, their validity is widely accepted.

First, the Chief Executive Officer (CEO) is the ultimate strategic planner in any organization. Whether through his or her actions or inactions, the CEO is ultimately responsible for the strategic direction the organization takes, and the active participation of the CEO in the strategic planning process is critical to its success.[3]

If the CEO is committed, then it is possible to gain the support and commitment of the organization's other senior managers. Senior managers in this context refers primarily to line managers, those with direct authority and responsibility for their portions of the enterprise. Their commitment is essential to the carrying out of any decisions that are reached, and their knowledge is an invaluable input in the planning process.

The primary role of planning staffs is, or should be, to facilitate the strategic management and planning process. Such staffs might perform independent analyses in order to help improve the quality of the discussions taking place, but they should not normally become advocates for a particular position. It is up to the CEO and the senior line

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[3] Although, in conformance with the literature, we use the term Chief Executive Officer (CEO) throughout this article, we are actually referring to any manager with clear authority over an organization or a part of an organization, whether public or private. The principles of strategic management are applicable to division managers, project managers, and so on, in addition to the CEO or other head of the entire organization.

managers to make these decisions.[4] Unfortunately, even the best managed organizations find it difficult to establish planning staffs which can walk the thin line between taking an active, but neutral, role in facilitating the strategic management process, and losing their neutrality by becoming advocates for a particular position. When the latter happens, staffs begin to usurp the responsibilities and authority of line managers, who then lose their confidence in and commitment to the management process.

In addition to these "first principles," theorists and practitioners are in broad agreement on a number of other aspects of strategic management. Seven additional principles are outlined here:

4. It is important to have good people in key management positions. It is no less true for being a truism that an organization can be no better than its people.[5]

5. Planning must include resource constraints on managers that force them to justify and make difficult decisions. A discipline must be imposed on the resource allocation process which is viewed by the participants as systematic and fair.[6]

6. The pace of change requires that senior management develop dynamic strategic planning processes. Strategic planning is often used in an effort to protect organizations against surprises and unwanted change. This makes it essentially a static process. Rather than view instability and change as threats,

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4 There is widespread agreement on the appropriate roles of CEOs, line managers, and planning staffs. See, for example, Hamermesh, Richard G., "Making Planning Strategic," *Harvard Business Review*, July-August 1986, pp.115-120; Gray, Daniel H., "Uses and Misuses of Strategic Planning," *Harvard Business Review*, January-February 1986, pp. 89-97; Yavitz, Boris and William H. Newman, *Strategy In Action* (Free Press, 1982); Roach, John D. C., and Michael Allen, "Strengthening the Strategic Planning Process," in Kenneth J. Albert, ed., *The Strategic Management Handbook* (McGraw-Hill, 1983), and Gluck, "Strategic Management: An Overview." Some corporate decisions, such as acquisitions involving new products or markets, may rely less heavily on inputs from line managers and more on planning staffs.

5 See, for example, Hambrick, Donald C., "The Top Management Team: Key To Strategic Success," in Glenn R. Carroll and David Vogel, eds., *Organizational Approaches To Strategy* (Ballinger, 1987); and Rock, Arthur, "Strategy vs. Tactics From A Venture Capitalist," *Harvard Business Review*, November-December 1987, pp. 63-67.

6 "If a plan is to be of any use at all...it almost has to raise tensions. Moreover, a strong position has to be adopted by the administration to ensure that some progress is made towards making real strategic choices...[P]lanning efforts...sometimes seemed to be the concatenation of shopping lists from various departments which did not eliminate any of the possibilities, make any difficult choices, or establish any clear consistent patterns. These plans may have made everyone happy but they did not provide a very clear guide for future action." Langley, Ann, "The Roles of Formal Strategic Planning," *Long Range Planning*, Vol. 21, No. 3, June 1988, p. 44. Although this is a perfect description of strategic planning in the Department of Defense, the organizations in this study were hospitals.

they should be viewed as opportunities, which the planning process can shape into advantages.[7]

7. Senior management should refrain from imposing goals which are too detailed; rather, they should set broad but clear objectives and allow (line) managers further down in the organization to develop meaningful and more detailed goals for their subordinates which are consistent with the top level objectives.

8. Strategies must be carefully communicated to the rest of the organization. People need to understand why there is a strategy, why there is *this* strategy, and why and how it should affect what they do.

9. Ideas must flow up as well as down through the organization if a strategy is to be viable. There are a lot of good ideas to be found throughout any organization which should be reflected in the strategic plan. If there is no mechanism for tapping into these ideas, then it is difficult to gain people's commitment to the strategy.[8]

10. "Implicit" strategies should be recognized and used. A distinction can be made between strategies which are deliberate and those which take shape with little formal direction. In many cases the organization already has many elements of an implicit strategy, which management can harness by molding these sub-strategies into a higher level, overall strategy.[9]

An organization which can put all of these factors together--and the consensus is that only a few of the country's best run organizations have been able to do so--is one which is practicing "strategic management." A strategically managed organization is one in which strategic planning is performed proactively throughout the organization as part of the expected responsibilities of all corporate managers. As Roach and Allen put it:

> [S]trategic planning becomes the basic management style on every level of the corporation as part and parcel of ongoing operations...Strategic planning is essentially the business of all managers, whether or not they are actually called into the ranks of strategic planners per se. Every manager's experience is a corporate resource that the best strategic planners will put to good use.[10]

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7 A valuable discussion of the relationship between the pace of change and the development of strategic planning processes over the past three decades is contained in Gluck, "Strategic Management: An Overview."

8 See, for example, John Roach and Michael Allen, "Strengthening the Strategic Planning Process."

9 This idea is most closely associated with the work of Henry Mintzberg. See, for example, "Crafting Strategy," *Harvard Business Review*, July-August 1987.

10 John D. C. Roach and Michael Allen, "Strengthening the Strategic Planning Process," p. 7-16 and 7-44.

Gluck makes the same point:

> What distinguishes these companies is the care and thoroughness with which management links strategic planning to operational decision making and then executes its plans...[11]

## III. THE MANAGEMENT OF PARTICIPATION

Suppose you are the Chief Executive Officer of an organization and you want to create a strategically managed organization. You realize that your involvement is critical and are ready to commit yourself fully. You agree that your line managers are the key players in the organization, and that good strategic management must be structured around them. You are committed to ensuring that the planning staff remains a small, neutral group which seeks to facilitate the planning and management process without usurping the authority of the organization's line managers. What do you do now?

Here there seems to be a gap in our understanding of strategic management processes. Having told the CEO what the results need to look like--that is, what the attributes of a good planning process are--there is nothing which tells the CEO what to do to put such a system in place, or how such a system operates. Many writers ignore or pay only lip service to the critical role to be played by the CEO, and little has been written on how to make strategic planning an integral part of a management system, so as to achieve strategic management. If line managers, as the primary implementors of strategy, are the key to success, then strategic planning processes must be designed around the requirement for their participation. Unfortunately, this recognition of the importance of participation has led to little discussion on how to manage such participation effectively.

### Decision Making and Participation

Participatory management is not a new concept, and the role that participation can play in decision making processes has received a great deal of attention from management theorists, psychologists, organizational behaviorists, and others who concern themselves with group decision making processes.[12] However, there appears to have been little effort to link this work on decision making to models of strategic planning and management, where the role of participation is often mentioned but essentially ignored.

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11 Frederick W. Gluck, "Strategic Management: An Overview," p. 1.29.

12 For a recent and excellent example, see Vroom, Victor and Arthur Jago, *The New Leadership: Managing Participation In Organization* (Prentice-Hall, 1988), pp. 15-48.

One important lesson from the extensive research on decision making is that every decision should be made with the appropriate involvement of the "acceptance set" and the "information set." The acceptance set consists of those people whose acceptance of a decision is required before it can be successfully implemented. In the negative these people might also be thought of as the resistance set. Little will change so long as these key people resist taking the necessary actions. The information set consists of those people who have information which could be used to make a better, a higher quality, decision. When making a decision on the purchase of light bulbs, the information and acceptance sets may consist of one person--no additional participation is needed. In developing a plan for, say, the introduction of a new product, these two sets contain a much larger number of people.

We thus face a situation in which the strategic planning and strategic management literature pays virtually no attention to the central role played by participation in successful strategic planning and management processes, while the organizational behavior literature on participation and decision making has not been applied to that class of complex decisions known as strategic planning. The existence of this gap is unfortunate, because the question that is central to any successful strategic management process is: who should participate and how should that participation be managed?

That there have been no attempts to link the two fields of strategic management and decision making may be due to the fact that analyses of participation are typically based on the implicit assumption that decisions are already being made within an existing and functioning management system, so that the question to be addressed is how best to reach an optimal decision within that system. The central issue with respect to strategic management, on the other hand, is--or should be--precisely what is the nature and function of a management system which recognizes the importance of participation.

Our experience with developing and implementing strategic management processes in the Department of defense has resulted in the development of some important connections between theories of participation and the principles of strategic management. We have developed a process in which all the appropriate participants--the acceptance and information sets--are included; in which real decisions are made, not just a consensus that consists of pabulum everyone is willing to agree to; and in which decisions can be communicated and their implementation can be followed up. In the next section we describe in detail the process we have developed and used over the past several years, which we call Structured Decision Making. We believe that it is techniques such as the ones we suggest for managing participation that are crucial to successful strategic management, and should therefore be the focus of attention for management theorists and executives alike.

## IV. STRUCTURED DECISION MAKING

The three most important aspects of good strategic management, as we have argued, are the role of the CEO, the role of line managers, and the role of staffs (see above, Section II). The initiation and operation of a successful strategic management process can be broken down into three key elements, based on these three attributes: (a) the support of top level management, (b) the composition and activities of a Steering Group, and (c) the role of the facilitator. We also add a fourth key element: (d) the recording, communication, and tracking of decisions.

Strategic management requires that an organization: (1) identify a set of organizational objectives, (2) develop a strategy for achieving these objectives, (3) agree on a detailed implementation plan for that strategy, and (4) see that the actions called for in the plan are carried out. What we describe is a process by which these actions can be successfully carried out.

### A. *The Support of Top Level Management*

The most critical element for success of strategic management is that the effort be initiated and supported by the senior executive in the organization. This may mean the chief executive officer of the organization, or the head of a division, project, or other sub-organization. Without his or her *active* interest and involvement, individuals in the rest of the organization will perceive--often correctly--that this effort will come to naught, because there is no guarantee that the results of their efforts will be accepted and implemented.

This top level involvement begins with the issuance of a charter for the Steering Group (described below), describing the problems and/or issues that the senior executive wishes to have addressed. (These issues might have to do with what strategic directions the organization should take in the years ahead, or they might deal with more specific issues, such as what to do about rising health care costs, or the efficiency of the R&D operation.) This charter must be sufficiently specific so as to help the Steering Group focus its efforts. At the same time it must be broad enough so that the members of the Steering Group do not feel that they are operating under excessive restrictions or that the results of their efforts are a foregone conclusion--the participants must be able to take ownership of their efforts.

The most serious problems we have experienced in assisting organizations in the Department of Defense have arisen when there was no charter and the senior executive was unwilling to issue clear guidance on what he wanted. (This is a particular problem in the Defense Department because authority and responsibility are so diffuse. It is often difficult to get a senior DoD executive to both take charge of a problem and convince others to accept his authority.) Under these circumstances, Steering Group members resist doing any work, both for reasons of traditional bureaucratic politics and resistance to change, and because they are unconvinced of the senior manager's commitment to the exercise and therefore don't want to waste their time on it.

## B. The Establishment Of The Steering Group

The Steering Group will, through a series of regular meetings, develop a set of objectives and a strategy to address the issues presented to it in its charter. It will then develop a detailed action or implementation plan for the organization that will lead to the achievement of those objectives. Finally, it will periodically revisit the decisions it has made to see how well they are being implemented and to determine whether the passage of time and events requires any alterations in their decisions. This activity must be recognized by the members as being an integral part of their day-today management activities. This is not a "program," distinct from or irrelevant to their other activities.

In selecting the members of the Steering Group, the senior manager must satisfy three criteria. First, the membership must include the "acceptance set." This typically means the senior line managers in an organization, along with other key staff managers as appropriate. This often poses an interesting problem when applied to our work with the Department of Defense. Not only is there often disagreement over who is line and who is staff, but many managers in staff positions quite literally do not understand the distinction between line and staff, or the difference in their responsibilities. Second, the Steering Group must include the "information set," those people whose knowledge of matters pertaining to the Steering Group's charter make their participation essential if the Group's report is to be of high quality. Such experts may come from within the organization, or from the outside.

Third, the Steering Group must contain no more than 17 people, with a preferred limit of 12. Both our own experience and that reported in the literature make clear that groups larger than this are too large to function effectively.[13] Rather than increase the size of the Steering Group, sub-groups are formed to address specific issues, with instructions to form recommendations and develop an action plan to implement their recommendations. It is the Steering Group's responsibility to review the progress of the sub-groups and ultimately to synthesize their work into the Steering Group's final product. We have found that one or more members of the Steering Group should also be members of each sub-group in order to ensure proper communication up and down the line. An additional advantage of sub-groups is that they provide a mechanism for communicating the work of the Steering Group to a larger number of influential people within the organization.

The goal of the Steering Group is to see that all important issues are raised and fully discussed. More specifically, this means that conflicts must be resolved without leading to an agreement that is the "least common denominator." To put it another way, what is required within the Steering Group is conflict without animosity that leads to real decisions, not pabulum.[14] Seeing that this happens is one of the key roles of the facilitator.

### C. The Role Of The Facilitator

The Steering Group requires the use of neutral facilitators. Facilitators have a number of responsibilities. First, they must be capable of providing a neutral forum for addressing the issues described in the charter and faced by the organization. Facilitators seek to assist discussion without taking positions on the substantive issues on which the participants are presumed to be experts. This includes stimulating and moderating discussions of controversial issues so as to ensure positive and meaningful outcomes, as discussed above. If internal facilitators are used (e.g., the corporate planning staff), they must be able to maintain their neutrality in the eyes of the other participants. In order for all individuals in the group to take ownership of their work, they must not feel that the particular interests of the person or organization who called the meeting have biased the results of the groups' efforts. Thus the importance of providing a neutral forum cannot be overstated, and it is not even advisable for the senior manager to act as the facilitator.

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13 See, for example, Warfield, John N., *Societal Systems: Planning, Policy, and Complexity*, John Wiley and Sons, New York, 1976.

14 Doyle and Straus make this same point by drawing a distinction between consensus and compromise. Consensus results in a solution everyone can live with. Compromise results in everyone backing down a little, and no one being happy with the final result. See Doyle, Michael and David Straus, *How To Make Meetings Work*, Jove Books, New York, 1976.

The most obvious role of the facilitators is to assist in the conduct of each meeting. They do this by helping to guide the discussions in a way that allows the Steering Group to write a report or plan that meets its objectives, as stated in the charter, as quickly and efficiently as possible. We find it most helpful to begin drafting a final report after the second or third meeting of the Steering Group. This works to improve the quality of the eventual report by getting people to talk about the important issues early on, and it also makes it easier to prepare regular progress reports. The use of progress reports is discussed in more detail below. The facilitators must take an active role in editing and synthesizing the written materials prepared by Steering Group members. This includes assisting the Steering Group in synthesizing the work of the sub-groups into its report.

A related function performed by facilitators is to see that other important members of the organization, who are not on the Steering Group, are kept abreast of its progress and have an opportunity to provide inputs to the group. The facilitator is the one who must see to it that the issues raised and decisions made by the Steering Group are properly recorded so that they can be communicated to the rest of the organization, and so that decisions can be followed up. We turn now to this issue.

## D. The Recording, Communication, And Tracking Of Decisions

One of the biggest problems faced by all decision making bodies is that of recording their decisions in such a way that: (1) all the participants can agree after each meeting on what was decided and what issues still need to be resolved, (2) people outside the group have enough information on what the decisions were to be able to carry them out, and (3) decisions can be reviewed at a later date to see if they have been properly implemented. Our experiences demonstrate that these problems can be solved through the use of two important meeting tools, a computer projection system and a continuously updated progress report.

The first of these, a computer projection system, is at once a simple and powerful method for improving the efficiency of a group's work, as well as recording, communicating, and tracking decisions. As discussions are held, ideas are generated, and decisions are made during a meeting, they are typed into a computer and appear on a large screen at the front of the meeting room. This technique offers three advantages over traditional techniques such as the taking of minutes, or the use of overhead transparencies or flip charts to record ideas.

First, it serves to provide a clear focus for the discussions, because each idea, as it is being discussed, appears on the screen before the whole group. Second, it provides people with an opportunity to clarify for one another the precise meanings they attach to particular words, and to make or argue about changes in these ideas on the spot. Thus, instead of arguing at the next meeting about what was meant by a certain phrase or comment that appeared in the minutes to the last meeting, that discussion can take place right away. The third advantage of the computer projection technique is that the results of each meeting can be immediately printed and distributed to the participants. In addition to minimizing disagreements about precisely what decisions were reached at the meeting, this allows people to begin work immediately on their assignments for the next meeting, and to discuss the results of the meeting with other colleagues who are not on the Steering Group.

Finally, this system provides an audit trail of the decision making process. It keeps a record not only of what decisions have been reached, but the reasons for those decisions. Particularly in the case of complex problems, understanding the reasons behind a decision is often crucial to being able to implement it in the way in which the original decision makers intended. In this way, it is also valuable in allowing senior executives to track how decisions are being implemented.

The second meeting tool, a progress report that is continuously updated to reflect the deliberations and decisions of the Steering Group, complements the use of the computer projection and printing system. Using the information already recorded during the Steering Group's meetings, the facilitators prepare a progress report which the participants use to keep others in the organization informed of the Steering Group's progress. Not only are top managers kept informed in this way, but their comments or concerns can be relayed back to the Steering Group and incorporated, as necessary, into their recommendations. In addition, the use of a common set of meeting records (from the computer projection and printing system) and progress reports means that the participants are able to communicate to others a consistent story about what they are doing. Disagreements are made clear during the meetings and during the preparation of the progress report, where they can be resolved.

## V. SUMMARY AND CONCLUSION

Where does communication and decision making take place in an organization? It is only a slight exaggeration to say that people do not read. Most communication takes place verbally, in formal and informal meetings. The techniques for Structured Decision Making that we have outlined here emphasize the critical importance that formal meetings play in facilitating--or failing to facilitate--communication and decision making within an organization. The nature and organization of the Steering Group, the role of the facilitator, the use of a projection system to record information during meetings, and the preparation of a progress report may seem at first to be details too insignificant for strategic planners to worry about. In fact, getting these things right is crucial to the establishment of a successful strategic management process.

We began by suggesting that the key question in strategic management is: who should participate and how should that participation be managed. The first part of that question was relatively easy to answer--it is the acceptance and information sets. We have therefore concentrated on suggesting answers to the second part of that question. When a CEO asks how to implement strategic management, we believe it is possible to provide a more complete answer than has previously been the case. Strategic management requires that the key managers in the organization participate in a process of identifying objectives, developing strategies and implementation plans to achieve those objectives, and periodically reviewing the implementation of its decisions. It is a continuous process of review, implementation, and feedback. Practically speaking, this means getting all the right people together, convincing them that what they are doing is important to the CEO and will be used, and then managing their participation in the decision making process effectively. Structured Decision Making, although not a cookbook for success, suggests some proven techniques that may be of value in a wide variety of organizations.

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